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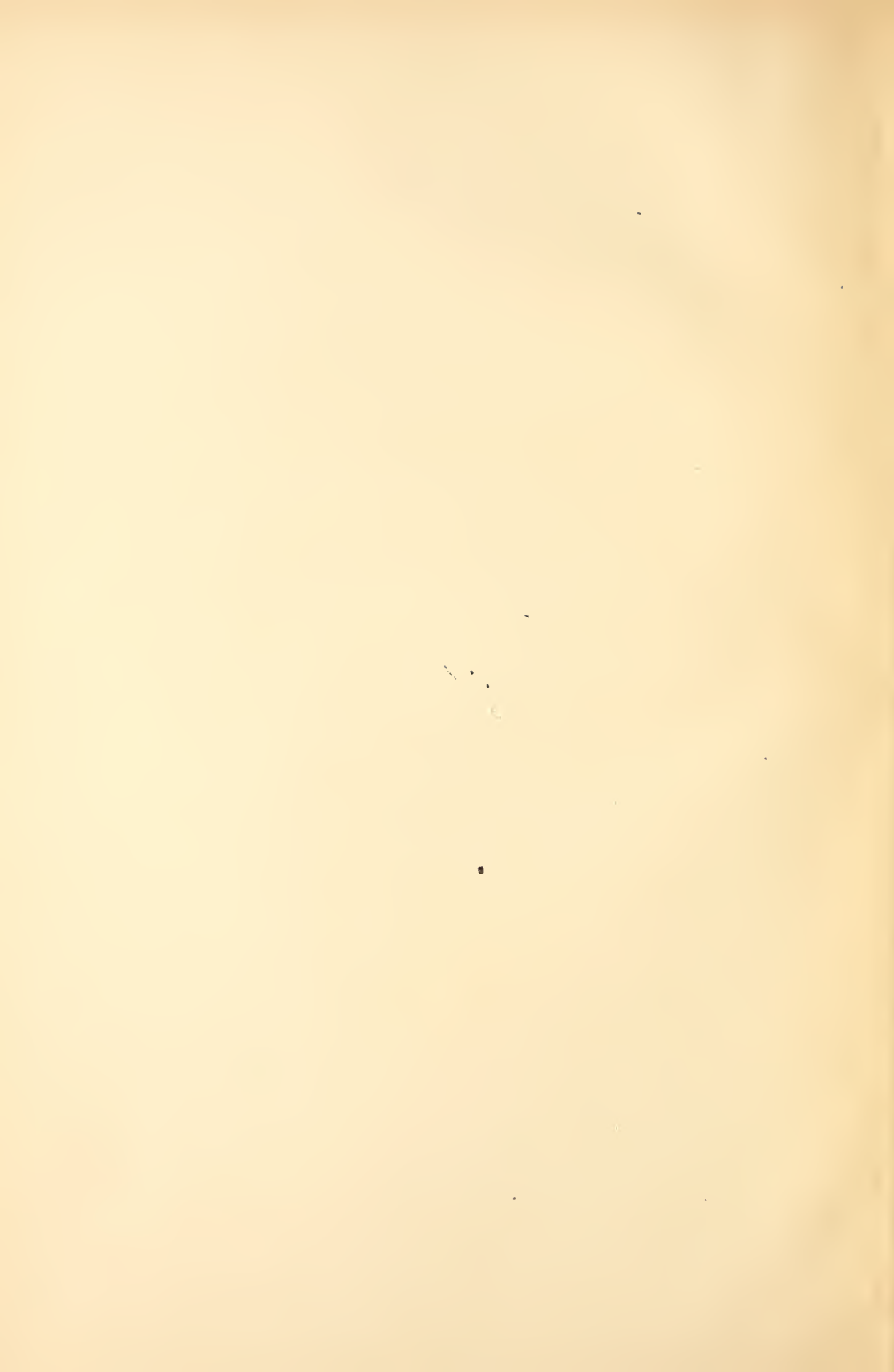












CARNEGIE INSTITUTION  
OF  
WASHINGTON

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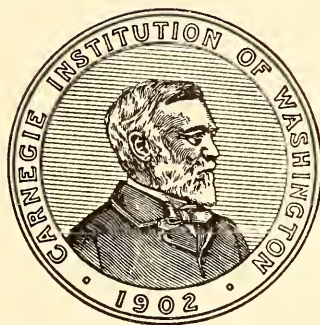
**YEAR BOOK No. 31**

**JULY 1, 1931, TO JUNE 30, 1932**

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WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 9, 1932

*Copy for Director's Office*



PUBLISHED BY CARNEGIE INSTITUTION OF WASHINGTON  
WASHINGTON, 1932



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## PRESIDENT

JOHN C. MERRIAM

## FORMER PRESIDENTS

\*DANIEL COIT GILMAN, 1902-04

\*ROBERT SIMPSON WOODWARD, 1904-20

## BOARD OF TRUSTEES

ELIHU ROOT, *Chairman*

HENRY S. PRITCHETT, *Vice-Chairman*

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EXECUTIVE COMMITTEE: HENRY S. PRITCHETT, *Chairman*; FREDERIC A. DELANO,  
W. CAMERON FORBES, CASS GILBERT, JOHN C. MERRIAM,  
STEWART PATON, ELIHU ROOT, FREDERIC C. WALCOTT

FINANCE COMMITTEE: HENRY S. PRITCHETT, *Chairman*; WM. CHURCH OSBORN,  
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AUDITING COMMITTEE: FREDERIC A. DELANO, *Chairman*; HOMER L. FERGUSON,  
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## FORMER TRUSTEES

*ALEXANDER AGASSIZ	1904-05	*WILLIAM LINDSAY	1902-09
*GEORGE J. BALDWIN	1925-27	*HENRY CABOT LODGE	1914-24
*JOHN S. BILLINGS	1902-13	*SETH LOW	1902-16
*ROBERT S. BROOKINGS	1910-29	*WAYNE MACVEAGH	1902-07
*JOHN L. CADWALADER	1903-14	*DARIUS O. MILLS	1902-09
*JOHN J. CARTY	1916-32	*S. WEIR MITCHELL	1902-14
*CLEVELAND H. DODGE	1903-23	*WILLIAM W. MORROW	1902-29
*WILLIAM E. DODGE	1902-03	*JAMES PARMELEE	1917-31
*CHARLES P. FENNER	1914-24	*WM. BARCLAY PARSONS	1907-32
SIMON FLEXNER	1910-14	GEORGE W. PEPPER	1914-19
*WILLIAM N. FREW	1902-15	*JULIUS ROSENWALD	1929-31
*LYMAN J. GAGE	1902-12	*MARTIN A. RYERSON	1908-28
*DANIEL C. GILMAN	1902-08	*JOHN C. SPOONER	1902-07
*JOHN HAY	1902-05	*WILLIAM H. TAFT	1906-15
*MYRON T. HERRICK	1915-29	*WILLIAM S. THAYER	1929-32
*ABRAM S. HEWITT	1902-03	*CHARLES D. WALCOTT	1902-27
*HENRY L. HIGGINSON	1902-19	*HENRY P. WALCOTT	1910-24
*ETHAN A. HITCHCOCK	1902-09	*ANDREW D. WHITE	1902-16
*HENRY HITCHCOCK	1902-02	*EDWARD D. WHITE	1902-03
*WILLIAM WIRT HOWE	1903-09	*HENRY WHITE	1913-27
*CHARLES L. HUTCHINSON	1902-24	*ROBERT S. WOODWARD	1905-24
*SAMUEL P. LANGLEY	1904-06	*CARROLL D. WRIGHT	1902-08

\*Deceased

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

## STAFF OF INVESTIGATORS

### *Department of Embryology:*

Established 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, Director  
CARL G. HARTMAN  
CHESTER H. HEUSER

MARGARET R. LEWIS  
WARREN H. LEWIS  
C. W. METZ

### *Department of Genetics:*

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics.

CHARLES B. DAVENPORT, Director  
A. F. BLAKESLEE, Assistant Director  
H. H. LAUGHLIN, Assistant Director  
A. G. AVERY  
H. J. BANKER  
R. W. BATES  
A. DOROTHY BERGNER

M. DEMEREC  
E. C. MACDOWELL  
OSCAR RIDDLE  
SOPHIE SATIN  
M. STEGGERDA

### *Geophysical Laboratory:*

Organized 1906, opened 1907.

ARTHUR L. DAY, Director  
L. H. ADAMS  
EUGENE T. ALLEN (Retired)  
TOM BARTH  
N. L. BOWEN  
C. N. FENNER  
R. E. GIBSON  
R. W. GORANSON  
J. W. GREIG  
J. H. HIBBEN  
F. C. KRACEK  
C. J. KSANDA

H. E. MERWIN  
G. W. MOREY  
CHARLES S. PIGGOT  
EUGENE POSNJAK  
H. S. ROBERTS  
J. F. SCHAIRES  
E. S. SHEPHERD  
GEORGE TUNELL  
H. S. WASHINGTON  
WALTER P. WHITE  
FRED E. WRIGHT  
E. G. ZIES

### *Division of Historical Research:*

Organized 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928.

A. V. KIDDER, Chairman

Section of Aboriginal American History:

SYLVANUS G. MORLEY  
EARL H. MORRIS  
H. E. D. POLLOCK  
O. G. RICKETSON JR.  
H. B. ROBERTS  
KARL RUPPERT  
A. LEDYARD SMITH

Section of United States History:

EDMUND C. BURNETT  
CHARLES O. PAULLIN  
FRANCE SCHOLES  
LEO F. STOCK

Section of the History of Science:

GEORGE SARTON  
ALEXANDER POGO

Associated Investigators:

W. A. HEIDEL  
ELIAS A. LOWE

### *Department of Meridian Astrometry:*

Established 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director  
SHERWOOD B. GRANT  
HEROY JENKINS  
HARRY RAYMOND

ARTHUR J. ROY  
W. B. VARNUM  
RALPH E. WILSON

## *Mount Wilson Observatory:*

Established 1904; George E. Hale, Director 1904-1923.

GEORGE E. HALE, Honorary Director  
WALTER S. ADAMS, Director  
F. H. SEARES, Assistant Director  
ALFRED H. JOY, Secretary  
A. S. KING, Supt. Physical Laboratory  
J. A. ANDERSON  
WALTER BAADE  
HAROLD D. BABCOCK  
THEODORE DUNHAM JR.  
FERDINAND ELLERMAN  
EDWIN P. HUBBLE

MILTON L. HUMASON  
PAUL W. MERRILL  
SETH B. NICHOLSON  
FRANCIS G. PEASE  
EDISON PETTIT  
R. S. RICHARDSON  
R. F. SANFORD  
SINCLAIR SMITH  
CHARLES E. ST. JOHN (Retired)  
GUSTAF STRÖMBERG  
A. VAN MAANEN

## *Nutrition Laboratory:*

Organized in 1907, opened 1908.

FRANCIS G. BENEDICT, Director  
T. M. CARPENTER

V. COROPATCHINSKY  
E. L. FOX

## *Division of Plant Biology:*

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology.

H. A. SPOEHR, Chairman  
JOHN BELLING  
JENS CLAUSEN  
FREDERIC E. CLEMENTS  
F. W. HAASIS  
H. M. HALL (Deceased)  
FRANCES L. LONG

DANIEL T. MACDOUGAL  
H. W. MILNER  
FORREST SHREVE  
JAMES H. C. SMITH  
H. H. STRAIN  
GEORGE R. WIELAND

## *Department of Terrestrial Magnetism:*

Organized 1904.

LOUIS A. BAUER, Director Emeritus (Deceased)  
J. A. FLEMING, Acting Director  
J. E. I. CAIRNS  
O. DAHL  
F. T. DAVIES (Leave of absence)  
C. R. DUVAL  
C. C. ENNIS  
H. W. FISK  
S. E. FORBUSH  
O. H. GISH  
H. W. GRAHAM  
JOHN W. GREEN  
L. R. HAFSTAD  
C. HUFF  
H. F. JOHNSTON

P. G. LEDIG  
R. H. MANSFIELD  
A. G. McNISH  
WILFRED C. PARKINSON  
W. J. PETERS (Retired)  
W. J. ROONEY  
W. E. SCOTT  
S. L. SEATON  
K. L. SHERMAN  
F. M. SOULE  
OSCAR W. TORRESON  
M. A. TUVE  
G. R. WAIT  
W. F. WALLIS  
F. W. WOOD

## *Investigators at Tortugas Laboratory, Summer 1932:*

PAUL BARTSCH, U. S. National Museum  
A. A. BOYDEN, Rutgers University  
L. R. CARY, Princeton University  
W. M. DE LAUBENFELS, Pasadena Junior College  
F. R. HAYES, Dalhousie University  
JAMES L. LEITCH, University of California  
WARREN R. LEWIS, Johns Hopkins University  
W. H. LONGLEY, Goucher College  
H. W. MANTER, University of Nebraska

*Investigators at Tortugas Laboratory, Summer 1932—Continued:*

W. L. SCHMITT, U. S. National Museum  
R. G. STONE, University of Missouri  
JOHN W. WELLS, Cornell University  
J. L. WILLIAMS, University of California  
SHIGEO YAMANOUCHI, University of Chicago

*Other Investigators:*

ALBERT MANN, Research Associate in Biology  
HARRY O. WOOD, Research Associate in Seismology

*Additional Research Associates connected with other Institutions:*

SEBASTIAN ALBRECHT (Dudley Observatory), Astronomy  
E. B. BABCOCK (University of California), Genetics  
A. M. BANTA (Brown University), Genetics  
J. BARTELS (Forstliche Hochschule, Eberswalde), Terrestrial Magnetism  
V. BJERKNES (University of Oslo, Norway), Meteorology  
G. BREIT (New York University), Terrestrial Magnetism  
J. P. BUWALDA (California Institute of Technology), Paleontology  
W. A. CANNON (Stanford University), Biology  
F. M. CARPENTER (Harvard University), Paleontology  
W. E. CASTLE (Harvard University), Biology  
RALPH W. CHANEY (University of California), Paleobotany  
A. H. COMPTON (University of Chicago), Physics  
K. T. COMPTON (Massachusetts Institute of Technology), Physics  
H. E. CRAMPTON (Columbia University), Biology  
L. R. DICE (University of Michigan), Biology  
A. E. DOUGLASS (University of Arizona), Ecology  
WALTER EDDY (Columbia University), Physiological Chemistry  
H. M. EVANS (University of California), Nutrition  
R. H. GODDARD (Clark University), Physics  
F. A. HARTMAN (University of Buffalo), Physiology  
J. H. JEANS (Royal Society of London), Astronomy  
REMINGTON KELLOGG (U. S. National Museum), Paleontology  
A. E. KENNELLY (Mass. Institute Technology), Terrestrial Magnetism  
D. N. LEHMER (University of California), Mathematics  
L. B. MENDEL (Yale University), Physiological Chemistry  
R. A. MILLIKAN (California Institute of Technology), Physics  
T. H. MORGAN (California Institute of Technology), Biology  
FRANK MORLEY (Johns Hopkins University), Mathematics  
EARLE B. PHELPS (College of Physicians and Surgeons), Physiology  
GREENLEAF W. PICKARD, Terrestrial Magnetism  
HENRY A. RUGER (Columbia University), Psychology  
G. OSCAR RUSSELL (Ohio State University), Physiology  
HENRY N. RUSSELL (Princeton University), Astronomy  
A. G. SHENSTONE (Princeton University), Physics  
JOEL STEBBINS (University of Wisconsin), Astronomy  
CHESTER STOCK (California Institute of Technology), Paleontology  
J. B. SUMNER (Cornell University), Biochemistry  
H. U. SVERDRUP (Chr. Michelsens Institutt, Bergen, Norway), Terrestrial Magnetism  
H. B. VICKERY (Connecticut Agric. Exper. Station), Physiological Chemistry  
LEWIS H. WEED (Johns Hopkins University), Anatomy  
DAVID WHITE (National Academy of Sciences), Paleontology  
R. R. WILLIAMS (Bell Telephone Laboratories), Physiological Chemistry  
BAILEY WILLIS (Stanford University), Seismology  
CLARK WISSLER (American Museum of Natural History), Archeology



## ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the endowment fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

## ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott,

## ARTICLES OF INCORPORATION

Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to

## ARTICLES OF INCORPORATION

organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.



## BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

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### ARTICLE I.

#### THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

### ARTICLE II.

#### MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

### ARTICLE III.

#### OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

## BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

### ARTICLE IV.

#### EXECUTIVE ADMINISTRATION.

##### *The President.*

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

### ARTICLE V.

#### COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio*

## BY-LAWS OF THE INSTITUTION

and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

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### ARTICLE VI.

#### FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

### ARTICLE VII.

#### AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES OF THE THIRTY-THIRD MEETING  
OF THE BOARD OF TRUSTEES





## ABSTRACT OF MINUTES OF THE THIRTY-THIRD MEETING OF BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 9, 1932. It was called to order at 10 a. m. by the Vice-Chairman of the Board, Mr. Pritchett.

Upon roll-call the following Trustees responded: W. W. Campbell, John J. Carty, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Cass Gilbert, Andrew J. Montague, Stewart Paton, John J. Pershing, Henry S. Pritchett, Theobald Smith, William Benson Storey, William S. Thayer, Frederic C. Walcott, William H. Welch, and George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the thirty-second meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1933 were authorized:

Pension Fund .....	\$ 60,000
Administration .....	67,960
Publications (including Division of Publications) .....	97,420
Departments and Divisions of Research.....	1,174,814
Minor Grants .....	101,000
General Contingent Fund .....	50,000
Special Emergency Reserve Fund.....	30,000
	1,581,194

Balloting for a new Trustee to fill the vacancy caused by the death of Wm. Barclay Parsons resulted in election of James W. Wadsworth jr., of New York.

Mr. Gilbert was reelected a member of the Executive Committee, and Messrs. Forbes and Walcott were named to fill vacancies in the Executive Committee created by the death of Mr. Parsons and by expiration of term of office of Mr. Osborn, who asked to be excused from further service on the Committee.

The meeting adjourned at 12.20 p. m.





REPORT OF THE PRESIDENT  
OF THE  
CARNEGIE INSTITUTION OF WASHINGTON

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In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit to the Trustees the following report on the work of the Institution for the fiscal year ending October 31, 1932. With this report are transmitted recommendations for appropriations required in the year beginning January 1, 1933.

In the death of William Barclay Parsons on May 9, 1932, the Institution lost one of its most loyal and earnest supporters. Beginning his term as trustee in 1907, General Parsons was continuously active in the service of the Institution for twenty-five years. He was a member of the Executive Committee from 1908 to the date of his death, and served as a member of the Finance Committee from 1922 to 1930. General Parsons received high honors for his work as an engineer in this country and in France during the World War. He was greatly interested in all activities of the Institution having relation directly or indirectly to engineering problems, and from a rich experience contributed advice of great value on the archæological program of the Institution in Middle America, with every aspect of which he was in constant helpful touch.

General Parsons gave freely of his time and counsel in deliberations of the Executive Committee and of the

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Finance Committee, serving as member of both bodies in a period when many of the most important research activities were planned and developed. During long service as a Trustee, he not only contributed sound judgment and wise counsel in direction of affairs of the Institution, but was recognized as one of the most consistent supporters of ideals for expression of which the Institution was founded.

Martin A. Ryerson, noted for his constructive interest in educational and philanthropic work, was elected a member of the Board of Trustees on December 9, 1908, and served continuously until December 1928, when he resigned on account of ill health and pressure of other obligations. He died on August 11, 1932. Mr. Ryerson had an important part in development of early work in the Institution, and served as a member of the Auditing Committee from 1924 to 1928.

Julius Rosenwald was elected to trusteeship on December 13, 1929, but by reason of continued ill health it proved impossible for him to attend meetings of the Board, in consequence of which he resigned, December 11, 1931. He died on January 6, 1932. During a lifetime devoted to philanthropic service, he made great contribution to advance in the cause of education and to furtherance of knowledge in many fields. His interest in work of the Institution was an important stimulus during his short period of service.

REPORT OF THE PRESIDENT, 1932

Louis A. Bauer entered the service of the Institution on April 1, 1904. It was due to availability of his exceptional talent and experience that the Trustees of the Institution established the Department of Terrestrial Magnetism. With Dr. Bauer as Director, the original plan of the Department contemplated wide-ranging international cooperation in conduct of a magnetic survey covering the entire globe. Results of comprehensive surveys, both on land and sea, have been of great scientific as well as of practical significance. On the basis of data obtained by the Department of Terrestrial Magnetism, it was possible for Dr. Bauer to extend his theoretical studies of fundamental problems concerning earth magnetism. The practical and theoretical contributions made by him in the course of the past thirty years are among the most valuable in the whole field of terrestrial magnetism. His published works are numerous and represent an element of exceptional importance in the progress of research in this field. Ill health compelled him to retire from active direction of work in the Institution on January 1, 1930, but until the date of his death on April 12, 1932, Dr. Bauer remained Emeritus Director of the Department of Terrestrial Magnetism and Research Associate of the Institution.

Harvey M. Hall became a staff member of the Institution on March 1, 1919. With headquarters at the University of California, he cooperated directly with Dr. Clements in ecological and taxonomic studies for many years. When the central lab-

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oratory of the Division of Plant Biology was established at Palo Alto, Dr. Hall moved to Stanford University and joined Dr. Spoehr and other members of the staff in initiating the group of important researches organized at that time. During absence of Dr. Spoehr for the period from September 1, 1930, to August 31, 1931, he served as Acting Chairman of the Division of Plant Biology.

The scientific work of Dr. Hall was of a pioneer character, and made notable contribution to the taxonomic study of difficult groups in the flora of western America. Experimental work with plantings, conducted in different localities at which both hereditary and environmental effects could be investigated carefully, was used as the basis of a new classification, and as a fresh approach to the problem of organic evolution. With unstinted energy and exceptional devotion to scientific pursuits, Dr. Hall coupled an extraordinary technique through which results having great influence on future studies in botanical science are certain to come. After having crossed the continent for the purpose of delivering a Carnegie Institution lecture summarizing his latest conclusions and methods, he passed away on March 11, 1932, in Washington.

The intense concentration upon critical questions which is possible in an agency devoted to fundamental research gives exceptional opportunity for contribution to knowledge. Long-continued operation increases the possibilities in such a program, provided enthusiasm for the subject is main-

Application  
of Research  
Results

tained. Question has sometimes been raised whether there is danger that in such an organization uninterrupted pursuit of purely idealistic aspects of science may work disadvantageously through turning attention away from what are called the practical realities of life. Is it possible that, by reason of this situation, a considerable percentage of the values observed will fail to come into human use? Consideration of the opportunity for human service which an agency devoted primarily to research can have through application of its results will always be important in reviewing the program of the Institution.

Between fundamental research and the incidents of day-to-day living the gap may seem extremely wide. So broad does this space appear that investigational activities are sometimes assumed to have value solely as intellectual exercise. This possibility is inherent in a case of this nature, since research concerns exploration in unknown fields. If we had acquaintance with the areas under investigation, the operation would not be research. Where studies are set up for the purpose of carrying knowledge forward along lines already laid down, it may be possible to make approximate prediction. But if the situation were fully known, the work would be merely verification and not fundamental research.

In the field of the unknown the paths are rarely well defined, and the process of exploration involves following clues leading now this way, now that. Sometimes the results are negative, but the contribution serves, none the less, to mark limits of knowledge. Not infrequently there



appears to be complete separation from everything having to do with practical living, but this does not diminish the ultimate value of results. It is also important to remember that the challenge of adventure in unknown regions, and the lure of possible discovery, make work of this type so attractive that accumulation of information continues.

Once the boundaries of knowledge have been moved forward, it becomes important to know the values represented by such advance. The time has long passed when it seemed desirable to inquire whether information about the universe or ourselves could exist which would not have human value. The unity of knowledge as we now begin to conceive it indicates that ultimately everything attains its place. That which seems insignificant may finally appear among the most important influences in life. Such is, in part, the justification for a program of intensive effort devoted to advancement of knowledge in the spirit of human service.

In development of research under conditions of modern social organization it is essential that such a relationship be set up as will make possible the greatest service through investigation, and at the same time permit the fullest use of what is secured.

Attainment of the highest values in an institution devoted to research depends in a measure upon the extent to which touch can be maintained with the fields of application, education, stimulation, and spiritual refreshment through which they may contribute to life. With this aspect of our problem in view the Carnegie Institution has recognized three important phases of

its responsibility relating to the use of research contributions. These activities include, first, a scheme for permanent and detailed record of results coming from researches, and so placed that they are available to specialists in all fields of science. To meet a second responsibility, continued effort has been directed toward study of the broader interpretation of work accomplished, and toward statement of conclusions in such manner that they may have the widest possible research and educational use.

Arising out of our program, there is now developing a third series of studies, designed to review research activities having application aspects so important that united effort of all contributing agencies may be desirable.

The most significant illustration of study on application problems is furnished by the work of a group of representatives from various departments, which is concerning itself with examination of investigations that may be helpful in dealing with critical questions of medical research. In developing this study it is not the intention to set up within the Institution activities corresponding to those of a medical research institute; nor is it necessarily true that fundamental modification of existing investigations would be brought about for the specific purposes of medical research. It is, however, desirable that resources of knowledge available within the Institution be placed at the disposal of investigators in other special fields, with the minimum of effort and the maximum of effectiveness for utilization.

In addition to wide cooperation between the Institution and research divisions of other agencies, one of the most important aids in the advance of investigation has developed through intimate relationship among research groups of the Institution itself.

Interrelation  
of  
Researches

With the departments and divisions situated where the conditions have been found most favorable, wide geographic distribution has been inevitable. But linking of interests is a stronger influence in the positive sense than is geographic separation viewed as a negative factor. The need for mutual support, and the stimulus of opportunity offered through the annual conferences and exhibits, has led to development of many connections having large influence in furtherance of the entire program. A factor of real significance in advancing some of the most important researches of the Institution is found in recognition of the possibility that, in extreme refinements of study, materials secured by specialists in other fields may be the elements most needed for success.

A very interesting statement of this problem, as it appears to one of the leading investigators of the Institution, is presented in the following abstract from a recent paper by Dr. Frederick H. Seares, of Mount Wilson Observatory:

. . . These interrelations are important because they greatly increase the scientific effectiveness of the Institution.

Everyone knows the contributions that come from highly specialized research, how little by little they increase our knowledge of the world in which we live, bring benefits to humanity, enrich our intellectual lives, and in the end subtly shape our thoughts about man's ephemeral existence in a universe whose duration eludes comprehen-



sion. It is not always recognized, however, that these results come about much faster when the specialist follows up connecting threads that lead into other fields of research. He then often finds an unsuspected interdependence which solves many riddles. Thus we learn much about plants by studying the animals that inhabit the same region. Plant distribution is a matter of soil and climate; more fundamentally it is a matter of geologic change, and only the paleobotanist, backed by the geologist as well as the physiographer, can tell why Monterey pines and redwoods grow where they do today. The life of the sea fluctuates with the physical-chemical conditions of its waters and is, therefore, also to be studied from the viewpoints of geophysics. . . . Cycles in tree growth point to fluctuating rainfall, which may be related to changes in the sun. Geology is linked to geophysics, while the geophysicist tells us how to make glass for our telescopes. Terrestrial magnetism offers analogies for the magnetic field of the sun. Physicist, geologist and geophysicist combine to investigate earthquakes, and with the astronomer they study the surface features of the moon and tell us its substance.

. . . Basic for all these things, of course, are the researches of the physicist and chemist and the powerful methods of mathematical analysis. The constitution of a star is a problem in atomic physics. The Carnegie Institution therefore aids Millikan and Noyes at the California Institute in order that they may join with the Mount Wilson Observatory in studying the constitution of matter, and supplements these efforts in its own Laboratory of Terrestrial Magnetism in Washington. It helps Michelson to repeat the famous Michelson-Morley experiment and to redetermine the velocity of light. In turn the astronomer directs the physicist to the stars as laboratories presenting conditions of pressure and temperature unattainable on the earth, under which he may test his theories of atoms.

Just as complicated world problems of today make unavoidable our realization that no situation may be considered wholly separate from what precedes and what follows, so in study of development in the human individual we are

Development  
of the  
Individual

learning the real significance of the idea that the child is father of the man. Present-day researches stress importance of both education and physical condition in the child as elements concerned in its development into an adequately equipped adult. Biological science, from its point of view, emphasizes the meaning of every stage in growth from the period when individuality is first defined.

As a part of our effort to improve the condition of mankind we must have sufficient knowledge of natural conditions to permit adjustment to the underlying forces which govern development and growth. For this purpose all information is important, whether it touch education of the child, guidance in its physical growth, or understanding of those fundamental processes through which the human organism takes form.

The embryologist looks upon the problem of human development as comprising everything involved in the chemico-physical, biological stages of the individual from the moment when the first cell begins its growth. Directed toward such a study there are under way in the embryological laboratory of the Institution investigations relating to all steps in development of the egg and of the early embryo; to problems involving growth of individual cells and body tissues; to the physiological aspects of the developmental process, including nutrition and metabolism of the embryo; and to the influence of those little-known secretions of various organs which guide or control development.

The carefully designed program of investigation in the embryological laboratory has progressed rapidly dur-

ing the past year. In combining study of tissue culture with motion picture technique, Dr. Warren H. Lewis has made notable progress in obtaining precise data relative to development of the individual cell. Especially significant in this work is the discovery of hitherto unknown behavior of the chromosomes, those infinitesimal but fundamental elements of the cell which are carriers of elements in heredity. In early stages of division the chromosomes show vigorous motion in shifting their position. This orienting activity increases as the median plate is formed in division, and is evidently due to forces residing in or about the chromosomes themselves instead of to a simple mechanical pull of spindle fibers. In another avenue of research, on the genetical aspect in the problem of development, Dr. Metz and Dr. DuBois have shown that in cleavage of the egg entire chromosomes are eliminated. On the basis of discoveries made by Dr. Lewis and Dr. Metz we must adapt ourselves to a new concept of the processes of cell division, both with reference to germ cells and to ordinary body cells.

In the later period of development, notable progress has been made in determining the precise nature of the embryo at different stages, giving for the first time exact data regarding the steps in evolution of the individual and the exact age of various embryonic stages.

The influence of substances formed by glands of internal secretion upon development of the egg or embryo has been illustrated in an exceptionally striking way by the experiments of Dr. Snyder and Dr. Wislocki, which show that growth of the egg may be initiated at unusual times and under unusual conditions, through introduc-

tion of substances known as hormones, which are apparently responsible for stimulation of the egg to division.

In close relation to investigations of the Department of Embryology is a group of studies in the Nutrition Laboratory directed toward determination of energy consumption in man, and in the types of animals with which the embryologists have been especially concerned in recent researches. The work of Dr. F. G. Benedict on comparison of metabolism in the monkey with that of man will, it is believed, lead ultimately to an estimate of values in the metabolic process of embryonic stages of man and of other creatures having a comparable developmental sequence.

In close relation to the studies of Dr. Benedict is the recently established research of Dr. H. C. Sherman, of Columbia University, on the problem of longevity as investigated by way of nutrition.

Having as its primary objective the nature of processes involved in origin of living beings, the Department of Genetics has properly directed a part of its inquiry to discussion of factors which control steps in growth of organisms after they take on individuality. It is fortunate that these investigations overlap and supplement those of the Department of Embryology, with which the Department of Genetics is in close cooperation.

Under the direction of Dr. Oscar Riddle in the Department of Genetics, research has been under way on special problems relating to control of biological processes

through substances produced by glands of internal secretion. These investigations have led in unexpected directions, and although the results range outside the narrower field of genetics, knowledge of the operations studied is essential for understanding of development in the individual. In the past year one of the most important contributions coming from these studies was the discovery of a substance having important relation to the process of milk secretion. The research on this material, to which the name "prolactin" has been given, was conducted by Dr. Riddle, Robert W. Bates, and Simon W. Dykshorn, of the Department of Genetics.

"Prolactin" has been obtained from the pituitary glands of cattle and sheep. Evidence is presented to show that the milk secretion process in the higher animals requires the influence of this particular element. It is also essential to the production of what is known as "crop milk" of pigeons. It had been known that the anterior pituitary gland contains a substance which excites milk secretion, but not until separation of the new hormone, "prolactin," could be accomplished, was the nature of the process revealed. This addition to knowledge marks a further advance toward understanding the biological mechanism and its mode of operation.

Organization of the Division of Plant Biology has encouraged close relationship among interests comprised in this field, and has made possible the focusing of widely differing views and techniques upon problems of biology for which solution must still be found. Continued concentration

**Search for  
Fundamentals  
in Biology**



of vision, or greater energy of attack at separated points, will undoubtedly bring increasing results. It is also true that re-statement of questions, and discovery of new viewpoints may accelerate advance at a rate not otherwise attainable. The following paragraphs from the annual report of Dr. H. A. Spoehr, Chairman of the Division of Plant Biology, present a significant interpretation of research on present problems in plant biology, and of questions that are important at this stage in development of general biological investigation.

Probably the most marked feature of research in biology since the beginning of the present century has been the phenomenal growth in efforts to apply the methods and concepts of physics and chemistry to biological problems. Stimulated by the method of thought—so successful in the physical sciences—of analysis in a search for simplicity, biology has largely devoted itself to the dictum that the activities of life are completely explicable in terms of mechanics, physics and chemistry. These efforts have now proceeded far enough to warrant the conclusion that the task of interpreting life phenomena on this basis will be vastly more difficult than was generally realized, and that the interpretation of coordination and integration of functions of a living organism and the reactions to its environment demands a store of information as yet largely non-existent in the disciplines of chemistry and physics. The physical environment itself is but imperfectly known and understood. Only a beginning has been made in gaining a more exact knowledge of the chemistry of the complex carbon compounds which play important rôles in living things. An examination of anatomical structure of plants in relation to function and to chemical composition of the component elements has hardly been begun. That, with such a background, advances should be slow in the interpretation of the activities of living things on the basis of physics and chemistry is by no means surprising. The task is vastly more laborious, time-consuming and exacting than investigations in the physical

sciences. But it is only by the patient, persistent and unspectacular accumulation of facts that a sufficiently sound ground work can be built, on the basis of which the dictum can be tested.

For over three hundred years the philosophy of biology has witnessed the swing of the pendulum between extreme vitalism and extreme mechanism. Each return of the pendulum has found the subject enriched by some basic observations. But it is doubtful whether philosophical speculations can be very fruitful in such a fragmentary state of knowledge, nor is it surprising under these conditions that the philosophical thought of either extreme should produce some resonance in the biological thought of the time.

Development of history on a basis comparable to that of the natural sciences has necessarily been slow by reason of vast complication in the events, and because the units as represented in human individuals and in the complexes of society present the most baffling subjects known to research.

**Definition  
of Problems  
in Early  
American  
History**

The rapid advance of natural science in recent decades is sometimes assumed to mean that study of man has been neglected, or that investigators in the field of the physical, mathematical, and natural sciences have been more effective than those devoted to human problems. But it is only through the perspective of years, or ages, that one may expect accurate evaluation of work in the human field as contrasted with other aspects of constructive study. Contrary to views commonly held, it may sometime appear that the present stage of advance in development of a working social or governmental organization for millions of people constitutes one of the greatest human achievements.



The immediate future of historical science seems one in which there will be focussed upon the study of human problems every type of effort that can be directed toward securing facts and derivation of interpretations in the form of what we call laws or modes of procedure.

The Division of Historical Research of the Institution has set for itself three major tasks: (1) the history and cultural interpretation of the sciences, (2) the history of certain aspects of penetration by European civilization into aboriginal America, and (3) the intense study of outstanding problems in the pre-Columbian story of the New World. Although these several phases of the problem may seem widely separated, actually the interpenetration and mutual support which develops is extremely important.

The mode of approach to consideration of questions involved in pre-Columbian history of America has been itself a research of unusual significance. Because of the importance of this method of investigation as applied to this particular problem, and as an important aspect of study in the field of human questions, the following statement is introduced from the annual report of Dr. A. V. Kidder, Chairman of the Division of Historical Research.

The two outstanding problems of pre-Columbian New World history are those of the peopling of the American continents and of the rise, in this hemisphere, of native civilization. The true position of the American Indian among the races of man cannot be evaluated until we know who he was, and whence, why, when and how he came; nor can the significance of his career be understood unless we have information as to what elements of culture he brought with him, how

## REPORT OF THE PRESIDENT, 1932

much he developed independently, and how he managed to build up the complex social, religious and economic structures which he had possessed for centuries before the coming of Europeans. These two questions of origin and growth are naturally fundamental for Americanists; they are also of extreme importance for the study of anthropology in the broader sense, for the one strikes back to the primary diffusions of the human stock, while the second links into the vast riddle of man's perennial upward striving.

From the limitless range of possible activities in New World research, this Section has elected to devote itself to the rise of native American civilization; and, within that field, on the principle of nuclear attack, to operate in two regions whose people were preeminent as builders of aboriginal culture, the Maya area of Middle America and the Pueblo country in the southwestern United States.

The Section's early work upon the Maya was purely archeological. Its major effort is, indeed, still devoted to recovery, by exploration and excavation, of factual data bearing upon the prehistoric period. But as such materials began to accumulate, and an attempt was made to interpret them in terms of history, it became clear that temples and pottery and ornaments, even hieroglyphic dates, were, in themselves, relatively meaningless. It was perceived, as must inevitably occur in any archeological research, that very little progress could be made toward an understanding of how these things came to be what they were and where they were, to say nothing of what they meant, without accurate knowledge of a host of environmental factors which the archeologist has neither the ability nor the time to study: the geology of the region, for example, its flora and fauna, its climate. Furthermore, there are many flank-attacks, so to speak, which may be made upon archeological problems, advances along collateral lines which result in accumulation of data to supplement or to facilitate comprehension of the meager and fragmentary products of excavation. Documentary history offers one such approach by giving us, along with many other things, a picture of native life at the time of the conquest, which is indispensable for interpretation of ancient remains. Ethnologists, working on the present-day Maya, learn further facts useful for the same end. Linguistic study is an invaluable aid in that it,

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permits deduction as to the specific and general relationships of groups, as well as concerning their contacts with people of other stocks. Racial questions must be considered in the light of data only to be gathered by the physical anthropologist. Medical research throws light upon the history of diseases. Agronomy tells us of the capabilities of the soil and the probable methods of its cultivation. And so one might almost indefinitely go on listing scientific activities indispensable for interpretation of the archeological record.

Unlike a study such as geology, which requires location at a point where the phenomena considered happen to be well expressed, conduct of research in physics has seemed relatively free from geographic limitations. In contrast to the idea that the laboratory by itself may be adequate for physical research, some of the most interesting developments of modern science are making it clear that laboratory conditions in the thin layer of atmosphere occupied by human beings differ radically from those of the universe as a whole.

To understand the physics of matter, as it exists, it is necessary to use the universe itself as a laboratory. So, with refined instruments and techniques, studies are made on the physics and chemistry of the sun and other stars; we consider the nature of conditions in interstellar space; we examine what seem to us extraordinary physical conditions of the earth's interior. At least to a limited extent, it now appears that for advantageous discussion of many physical and chemical problems geographic conditions have importance.

The extensive program of investigations organized under the Department of Terrestrial Magnetism in the Institution centers on magnetism in relation to phenomena of the earth as a whole. Much of the effort expended in these researches during the past twenty-eight years was properly directed toward accumulation of data concerning magnetic values recorded on different parts of the earth at approximately the same time, or at different times in the same places.

The information regarding geographic differences in magnetism now available gives a picture of variation in physical phenomena of the earth as a unit. Supplementing records of magnetic values, observations have been made on electrical changes in the atmosphere, and in the earth itself, which also show relation to geographic range. In further fields of observation, record has been made of influences, other than light and heat, which seem derivable from bodies outside the earth. Such are effects assumed to arise from magnetic phenomena on the sun, and the measurable values of cosmic rays, or penetrating radiation.

Correlated with the data obtained from observations conducted with reference to geographic situation, this Department is engaged in laboratory researches on magnetism considered as a physical phenomenon without reference to location. These investigations have contributed data of much importance in atomic physics. As they are carried on in cooperation with many other agencies, John A. Fleming, Acting Director of the Department, has recently invited into conference a group of leading investigators for the purpose of advising with

the Department concerning opportunities and responsibilities of the Institution in this field. Among subjects discussed, consideration was given to development of the most effective relations between the laboratory aspects of basic physics and those phases of departmental research which have developed from study of physical phenomena of the earth as a whole.

In close relation to some of the most fundamental researches in physics, recent studies on penetrating radiation, or influence of the cosmic ray, turn to the laboratory of the universe for data, and depend in an important way upon values of geographic location. In addition to contrast between penetrating effects obtained at high elevations and those at sea level, it has become important to examine results secured under variations of latitude, or with reference to location of the magnetic poles. In these researches difference in geographic situation on the earth has a relation to questions concerning geography of the universe outside.

In an interesting way important observations in basic physics, such as those on penetrating radiation, conducted by Dr. Millikan and by Dr. Arthur Compton in cooperation with the Institution, with support of Carnegie Corporation of New York, are directed toward a geographic aspect of investigation, as is done in the broad studies of terrestrial magnetism. On the other hand, our researches relating to magnetic variation have naturally developed in the direction of laboratory researches involving the most fundamental questions of atomic physics.



**Relations of  
Geophysics  
and  
Seismology**

As the geographical range of human experience is practically confined to the surface of the earth we can be expected to have only a limited appreciation of conditions of temperature and pressure which change so rapidly as we rise above sea level or enter the crust of the earth. The thin mixture of atmosphere at a level of ten to fifteen thousand feet elevation brings marked change in conditions of pressure, while penetration of a corresponding distance downward along the four thousand mile radius of the earth produces another variation, dependent upon mass of the rocks penetrated.

We probe the atmosphere through exploration of mountain heights, penetration by airplanes and balloons, or by study of radiation which comes to us from outside regions. Conditions within the earth we may calculate mathematically from the size and mass of material assumed to constitute the earth's bulk. Estimate of interior earth conditions to a limited distance we make also through borings. Other experience we gather from examining remains of ancient geological formations that give evidence of having been buried at some remote time to a depth much greater than any we reach by man-directed operations.

A method which has recently begun to make its definite contribution to knowledge of earth structure is found in the accurate measurement of vibrations transmitted through the earth as result of earthquakes. As concerning the nature of these vibration effects, it is important to know the elastic properties of rocks on the surface of the globe, together with those under the enormous pres-

asures produced by weight of material resting upon the inner portions of the earth. It is essential too that we have this information regarding these rocks at high temperatures as well as at the low temperatures of the earth's surface.

That these problems of geophysics and seismology are related is evident. It is clear also that both groups of questions naturally connect themselves with geological research on the structure and history of the earth. On another side they are based upon results coming from investigation in the most fundamental aspects of physics. It is this type of relationship, developed through cooperation of the Geophysical Laboratory and the Seismological Laboratory, and through close touch with agencies such as California Institute of Technology, at Pasadena, that is now making possible advance in knowledge of the earth's crust.

In the annual report of Mount Wilson Observatory, Dr. Adams, Director of the Department, has called especial attention to methods and processes which have made possible advances in fundamental investigation. Often the way to marked progress in science is opened by new instruments which permit extension of observational data. At other times advance becomes possible through discovery of new points of view, or new theories which turn attention toward significant arrangements of facts not previously understood. In the past year, two advances in instrumental development have had important influence upon work of the Observatory.

**Contribution of  
Instruments  
and Technique  
to Astronomical  
Research**



One of these contributions to progress in research has been made by Dr. Joel Stebbins, of the University of Wisconsin, a Research Associate of the Carnegie Institution, who has resided for a portion of the year at Mount Wilson Observatory. This important work was done by study of the amplification of small currents involved in photoelectric photometry of stars by means of the thermionic tube, an instrument through use of which it is possible to render currents perceptible which otherwise would escape detection.

Mr. Whitford, assistant to Dr. Stebbins at the Washburn Observatory at the University of Wisconsin, has succeeded in multiplying the effective sensitivity of this instrument at least fourfold. Construction of an instrument of this design for the 100-inch telescope is expected to increase the useful measures of the light of nebulae from the 13th nearly to the 15th magnitude.

In another direction contribution by Dr. C. E. K. Mees, Director of the Research Laboratory of the Eastman Kodak Company, to development of photographic plates of high sensitiveness to the red and infra-red portions of the spectrum opens the way for researches heretofore impracticable. It extends the range of spectroscopy into a new and extremely important region. Discovery and identification of new bands in planetary spectra, the photographing of important series of hydrogen lines in the spectra of the stars, and the extension of the spectrum of the sun far into the infra-red are a few of the extremely important results made possible by the work of Dr. Mees.

CARNEGIE INSTITUTION OF WASHINGTON

In past years the publication policy of the Institution has supported the idea of including in the Carnegie Institution series, monographic studies by investigators not members of the Institution staff, when such contributions have represented especially significant researches requiring this form of presentation. A few publications of this character have been issued within recent years, but the service has been limited by reason of the responsibility for publishing results coming from investigations planned and conducted by the Institution.

It seems clear from study of obligations involving support of researches that provision for publication, or recording of results, is a normal part of every program. With the increase of material arising from long-continued investigations initiated through the Institution, the responsibility for publication has grown to such an extent as practically to prevent acceptance of many important monographs by distinguished students, even when the results are of great value in fields in which the Institution is engaged.

As in past years, the distribution of published results of our work shows approximately equal representation in the quantity of material printed in the Institution series and that appearing in other channels made available by cooperation through partial payment of costs by the Institution.

In the past year the Division of Publications and a committee of the Institution staff under chairmanship of Dr. Fred. E. Wright have conducted an intensive study of our entire publication program. This research on

plan and operation has been guided by desire to learn whether there are aspects of the system which could be so modified as to make both the record and the interpretation of scientific contribution more effective.

The study on publication problems has covered questions of form, organization, and distribution of the Carnegie Institution series, as also the betterment of opportunity through other channels. Careful attention has been given to purpose and function of the Year Book; to its value as a record of administrative significance; to its contribution toward general interpretation of the work of the Institution; and to its use in representing current advances in fields of research in which the Institution is engaged. A re-study has also been under way of the various means used for interpretation and for public announcement of research contributions. This includes all that has originated through Carnegie Institution lectures, exhibits of research results, and announcement of contributions through regularly organized releases or notices to the press.

Careful handling of Institution investments by the Finance Committee and Investment Office has prevented such reduction of income during 1932 as to retard progress of our research program. The small losses for the past year have been cared for without difficulty through the Special Emergency Reserve Fund, in accordance with provision made in the budget plans for 1932.

**Financial  
Situation  
and  
Budget of  
1933**

The maintenance of research, made possible through safeguarding of resources, represents in reality much

more than mere absence of interruption in program. It means continuity of investigations in which the value is in large measure dependent upon continued observation over a considerable period. In some instances failure to carry a particular research over a period of several years might mean large loss of value in all of the work actually completed.

In planning for 1933 it has been considered wise to prepare a budget on the basis of possible income reduction considerably larger than in 1932. Retrenchments made necessary by this plan have been worked out satisfactorily by fullest cooperation of departments. The salary scale of regular staff members has been maintained, and it is hoped that bettered financial conditions will permit holding to the present standard of compensation. The gradual increases of salary in recent years have not as yet made possible lifting the scale to a level comparable to that of institutions with staff of equivalent scientific or academic rank. It is believed that these gains, made so slowly, should not be sacrificed unless financial conditions indicate necessity for such action by reason of long-extended reduction of income.

Budget plans for 1933, as now outlined, will permit maintaining the major program of the Institution with the reductions so arranged as to concern in part the gathering of additional data which could be deferred until a later time. The attitude of the staff of the Institution toward such reduction as has been necessary demonstrates that the volume of work will not be diminished, and that the long-continued progress in refinement of standards will be maintained.

# REPORT OF THE PRESIDENT, 1932

## FINANCIAL STATEMENT

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees, December 11, 1931, and revertments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year are shown in detail in the table.

*Financial statement for fiscal year ending October 31, 1932*

	Balances unallotted Oct. 31, 1931	Trustees' appropri- ation Dec. 11, 1931	Revert- ments and transfers Nov. 1, 1931, to Oct. 31, 1932	Total available 1932	Executive Committee allotments 1932	Transfers by Execu- tive Com- mittee	Unallotted balances Oct. 31, 1932
Large Grants:							
Embryology.....		\$77,700	\$600	\$78,300	\$78,300		
Genetics.....		145,710	12,750	158,460	158,460		
Geophysical Laboratory..		181,184	49,200	230,384	230,384		
Historical Research.....		167,725	4,835.75	172,560.75	172,560.75		
Tortugas Laboratory.....		15,500	1,000	16,500	16,500		
Meridian Astrometry.....		35,220		35,220	35,220		
Mt. Wilson Observatory..		242,750	4,150	246,900	246,900		
Nutrition Laboratory.....		52,980	500	53,480	53,480		
Plant Biology.....		138,325	4,050	142,375	142,375		
Terrestrial Magnetism....		205,450		205,450	205,450		
Minor Grants.....	\$58.46	149,500	12,832	162,390.46	161,225		\$1,165.46
Publications.....	5,664.68	102,670	9,666.57	118,001.25	114,010.86		3,990.39
Administration.....		71,218	3,383.33	74,601.33	74,601.33		
Pension Fund.....		60,000		60,000	60,000		
General Contingent Fund...	30,075.77	50,000	32,935.88	113,011.65	8,524.36	\$44,183.33	60,303.96
Sp'l. Emer., Reserve Fund..		30,000		30,000	30,000		
	35,798.91	1,725,932	135,903.53	1,897,634.44	1,787,991.30	44,183.33	65,459.81



# CARNEGIE INSTITUTION OF WASHINGTON

The aggregate of receipts from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution are shown below; the grand total of these to date is \$80,134,537.26.

## Aggregate of financial receipts

Year ending Oct. 31	Interest on bonds and bank deposits	Sales of publications	Refunds on grants	Miscellaneous items	Total
1902	\$250,009.70	.....	.....	\$1,825.52	\$251,835.22
1903	505,867.10	\$2,286.16	.....	101.57	508,254.83
1904	533,004.26	2,436.07	\$999.03	.....	536,439.36
1905	525,698.59	3,038.95	200.94	150.00	529,088.48
1906	527,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	522,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	567,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	614,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	610,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	989,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,131,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,149,670.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,164,382.80	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,168,263.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,184,001.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,201,111.35	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,230,891.47	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,251,141.98	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,272,000.28	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,282,652.47	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,287,525.61	14,081.84	9,395.66	34,527.38	1,345,530.49
1923	1,306,828.85	13,841.76	9,739.17	1,720,808.90	3,051,218.68
1924	1,308,556.56	11,994.21	18,663.38	409,712.28	1,748,926.43
1925	1,379,281.51	13,680.74	14,315.03	825,156.17	2,232,433.45
1926	1,356,213.02	14,039.02	44,766.64	167,898.35	1,582,917.03
1927	1,385,436.33	10,032.42	19,049.80	1,814,461.93	3,228,980.48
1928	1,715,492.49	10,924.25	31,144.42	26,068,636.68	27,826,197.84
1929	1,593,667.77	8,925.91	110,724.28	6,367,398.68	8,080,716.64
1930	1,644,909.66	9,468.94	61,767.38	1,922,049.30	3,638,195.28
1931	1,682,548.03	8,482.73	30,359.12	2,213,749.06	3,935,138.94
1932	1,707,165.98	5,286.23	25,304.41	1,240,511.49	2,978,268.11
Total	34,050,087.66	307,024.47	546,436.24	*45,230,988.89	80,134,537.26

\* Of this amount \$38,002,271.21 came from the sale of bonds; \$52,015.74 from the Colburn Estate; and \$7,074,281.24 from the Carnegie Corporation of New York.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified

# REPORT OF THE PRESIDENT, 1932

under five heads: (1) Investments in bonds; (2) large projects; (3) minor grants and payments from Pensions, Insurance, and General Contingent Funds; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution.

*Aggregate of expenditures*

Year ending Oct. 31	Purchase of bonds	Large projects	Minor grants and payments from Special Funds	Publications	Administration	Total
1902	.....	.....	\$4,500.00	.....	\$27,513.00	\$32,013.00
1903	\$100,475.00	.....	137,564.17	\$938.53	43,627.66	282,605.36
1904	196,159.72	\$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
1923	1,715,537.72	930,395.95	232,344.69	89,402.06	63,493.46	3,031,173.88
1924	440,921.24	939,739.67	230,291.90	87,790.74	65,076.47	1,763,820.02
1925	861,583.20	979,615.36	225,307.45	103,531.67	67,266.71	2,237,304.39
1926	178,817.80	1,060,525.36	254,977.20	84,526.23	65,871.48	1,644,718.07
1927	1,623,071.17	1,164,136.05	258,709.17	85,221.42	67,283.11	3,198,420.92
1928	26,010,438.19	1,208,942.20	281,308.76	93,571.02	73,052.60	27,667,312.77
1929	6,428,356.99	1,341,868.84	324,121.39	95,164.52	69,549.41	8,259,061.15
1930	1,864,870.66	1,264,258.33	274,811.52	113,254.12	73,437.13	3,590,631.76
1931	2,157,884.88	1,301,547.21	288,786.36	113,094.11	76,055.89	3,937,368.45
1932	1,214,321.43	1,320,697.90	260,199.37	125,921.05	73,898.71	2,995,038.46
Total	47,942,522.55	23,052,179.48	5,139,795.74	2,022,402.06	1,678,648.08	79,835,547.91



# CARNEGIE INSTITUTION OF WASHINGTON

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings and equipment of departmental establishments, the following sums have been expended since the foundation of the Institution:

<i>Real Estate and Equipment, Original Cost</i>		
Administration (October 31, 1932):		
Washington, D. C.		
Building, site and equipment.....		\$403,155.09
Division of Plant Biology (September 30, 1932):		
Palo Alto, Calif.		
Buildings and grounds.....	\$157,903.63	
Laboratory .....	45,180.56	
Library .....	20,933.35	
Operating appliances.....	22,620.73	
		246,638.27
Department of Embryology (September 30, 1932):		
Baltimore, Md.		
Library .....	2,824.79	
Laboratory .....	12,185.74	
Administration.....	6,552.03	
		21,562.56
Department of Genetics (September 30, 1932):		
Cold Spring Harbor, Long Island, N. Y.		
Buildings, grounds, field.....	286,648.25	
Operating.....	25,352.74	
Laboratory apparatus .....	20,364.30	
Library .....	36,925.84	
Archives.....	45,488.90	
		414,780.03
Geophysical Laboratory (September 30, 1932):		
Upton St., Washington, D. C.		
Building, library, operating appliances.....	211,764.22	
Laboratory apparatus.....	136,005.47	
Shop equipment.....	14,929.01	
		362,698.70
Division of Historical Research (Sept. 30, 1932):		
Tower Bldg., Washington, D. C.		
Operating.....	11,197.65	
Library.....	7,065.77	
		18,263.42

# REPORT OF THE PRESIDENT, 1932

## Tortugas Laboratory (September 30, 1932):

Tortugas, Fla.		
Vessels .....	\$30,930.43	
Buildings, docks, furniture and library .....	12,130.86	
Apparatus and instruments .....	9,322.55	
	<hr/>	\$52,383.84

## Department of Meridian Astrometry (September 30, 1932):

Albany, N. Y.		
Apparatus and instruments .....	4,846.84	
Operating .....	5,070.42	
	<hr/>	9,917.26

## Nutrition Laboratory (September 30, 1932):

Boston, Mass.		
Building, office and shop .....	131,449.08	
Laboratory apparatus .....	36,046.29	
	<hr/>	167,495.37

## Mount Wilson Observatory (August 31, 1932):

Pasadena, Calif.		
Buildings, grounds, road and telephone lines .....	202,474.64	
Shop equipment .....	45,834.44	
Instruments .....	659,494.04	
Furniture and operating appliances .....	194,524.96	
Hooker 100-inch reflector .....	604,840.09	
	<hr/>	1,707,168.17

## Department of Terrestrial Magnetism (September 30, 1932):

Broad Branch Road, Washington, D. C.		
Building, site and office .....	215,659.52	
Survey equipment .....	94,306.60	
Instruments, laboratory and shop equipment .....	159,581.00	
	<hr/>	469,547.12
		<hr/>
		3,873,609.83

# CARNEGIE INSTITUTION OF WASHINGTON

## PUBLICATIONS

Sales of Publications and Value of those on Hand

Amounts received from purchases of the Index Medicus, from sales of the Year Book, and from sales of all other publications for each year since the foundation of the Institution are shown in the table below.

Table showing sales of publications

Year	Index Medicus	Year Book	Miscellaneous books
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
1930.....	363.65	127.85	8,977.44
1931.....	574.30	159.38	7,749.05
1932.....	119.35	80.60	5,086.28
Total....	111,509.30	1,902.05	193,613.12

At the end of the fiscal year there are on hand 85,405 volumes of miscellaneous publications and Year Books, having a sale value of \$263,449.45, also 1439 complete volumes of the Index Medicus which together with miscellaneous numbers

# REPORT OF THE PRESIDENT, 1932

have a value of \$14,581. Publication of the Index Medicus was taken over by the American Medical Association in 1927.

**Growth and Extent of Institution's Publications** The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. 630 volumes, which embrace a total of 186,558 pages of printed matter, have thus far been issued.

*Statistics of publications*

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
1925.....	24	3,970	1,277	5,247
1926.....	14	4,552	850	5,402
1927.....	17	4,520	2,089	8,609
1928.....	15	4,495	1,044	5,539
1929.....	12	4,938	452	5,390
1930.....	15	4,096	844	4,940
1931.....	14	4,017	1,343	5,360
1932.....	16	2,155	2,588	4,743
Total..	630	134,229	52,333	185,558

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The publication of 20 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of \$52,175. The following list gives the titles and names of authors of the publications issued. It includes 16 volumes, with an aggregate of 2155 octavo pages and 2588 quarto pages. Fourteen additional volumes are now in press.

LIST OF PUBLICATIONS ISSUED BY CARNEGIE INSTITUTION OF WASHINGTON  
DURING THE YEAR ENDING OCTOBER 31, 1932

- Year Book No. 30. 1931. Octavo, xix+63-505 pages, 2 plates, 2 text-figs.
- No. 392. Leland, Waldo G. Guide to Materials for American History in the Libraries and Archives of Paris.  
Vol. I. Libraries. Octavo, xiii+343 pages.
- No. 401. Paullin, Charles O. (Edited by John K. Wright.) Atlas of the Historical Geography of the United States. Quarto, xv+162 pages, 166 plates in color.
- No. 410. Crampton, Henry E. Studies on the Variation, Distribution and Evolution of the Genus *Partula*: The Species Inhabiting Moorea. Quarto, vi+335 pages, 24 plates, 10 text-figs.
- No. 417. Aitken, Robert G. New General Catalogue of Double Stars within 120° of the North Pole. Quarto.  
Vol. I. pages lxxviii+707, 1 text-fig.  
Vol. II. pages i+708-1488.
- No. 418. Contributions to Paleontology from Carnegie Institution of Washington, containing the following papers:  
I. (Reported in 1931.)  
II. (Reported in 1931.)  
III. Gazin, C. Lewis. A Miocene Mammalian Fauna from South-eastern Oregon. Pages 37-86, 6 plates, 20 text-figs.  
IV. Stock, Chester. Additions to the Mammalian Fauna from the Tecuya Beds, California. Pages 87-92, 1 plate.  
V. Furlong, Eustace L. A New Genus of Otter from the Pliocene of the Northern Great Basin Province. Pages 93-103, 2 plates.  
VI. Packard, E. L. A Contribution to the Paleozoic Geology of Central Oregon. Pages 105-113.
- No. 420. Goldsmith, G. W., and A. L. Hafenrichter. Anthokinetics: The Physiology and Ecology of Floral Movements. Octavo, vi+198 pages, 29 plates, 34 text-figs.
- No. 424. Thompson, J. Eric, Harry E. D. Pollock and Jean Charlot. A Preliminary Study of the Ruins of Coba, Quintana Roo, Mexico. Quarto, vi+213 pages, 1 map, 18 plates, 70 text-figs.
- No. 425. Benedict, Francis G. The Physiology of Large Reptiles. With Special Reference to the Heat Production of Snakes, Tortoises, Lizards and Alligators. Octavo, x+539 pages, 106 text-figs.

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- No. 426. Bingham, Harold C. Gorillas in a Native Habitat. Octavo, iv+66 pages, 22 plates, 5 text-figs.
- No. 427. Castle, W. E., and Paul B. Sawin. Contributions to the Genetics of the Domestic Rabbit. ii+50 pages, 12 pls.  
 I. Castle, W. E.—English and Dutch Spotting and the Genetics of the Hotot Rabbit.  
 II. Sawin, Paul B.—Albino Allelomorphs of the Rabbit with Special Reference to Blue-eyed Chinchilla and its Variations.
- No. 428. Davenport, Charles B. The Genetical Factor in Endemic Goiter. Octavo, iv+56 pages, 9 charts, 6 text-figs.
- No. 429. Howard, Hildegard. The Eagles and the Eagle-like Vultures of the Rancho La Brea Pleistocene. Octavo, iii+82 pages, 29 plates.
- No. 433. Contributions to Embryology, Vol. XXIII, Nos. 134 to 138. Quarto, iii+267, 27 plates, 58 text-figs.  
 Hartman, Carl G.—Studies in the Reproduction of the Monkey *Macacus (Pithecus) rhesus*, with Special Reference to Menstruation and Pregnancy. (Cont. No. 134.)  
 Wislocki, George B.—On the Female Reproductive Tract of the Gorilla, with a Comparison of that of other Primates. (Cont. No. 135.)  
 Limson, Marciano—Observations on the Bones of the Skull in White and Negro Fetuses and Infants. (Cont. No. 136.)  
 Squier, Raymond R.—The Living Egg and Early Stages of its Development in the Guinea-Pig. (Cont. No. 137.)  
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- No. 434. Steggerda, Morris. Anthropometry of Adult Maya Indians. Octavo, iv+113 pages, 11 plates.
- No. 436. (Preprint) Contributions to Archeology from Carnegie Institution of Washington. Quarto.  
 Smith, A. Ledyard—Two Recent Ceramic Finds at Uaxactun. 25 pages, 5 plates (4 in color), 9 text-figs.

### SUPPLEMENTARY PUBLICATIONS

- No. 4. Los Mayas de la Región Central de América.  
 I—El Problema Arqueológico.  
 II—El Templo de los Guerreros.  
 III—La Restauración del Mosaico de Turquesas.  
 IV—Los Bajo Relieves del Templo de los Guerreros.  
 V—Las Pinturas del Templo de los Guerreros.

### MISCELLANEOUS

#### News Service Bulletin:

- An Evolving Universe, Pt. I—Innumerable Star Systems, by Sir James Jeans, vol. II, No. 23, 155–157, 4 illus.; Pt. II—States and Stages in Development, by Sir James Jeans, vol. II, No. 24, 158–162, 11 illus.; Notes on Institution Affairs: The Exodus of the Maya, 163–164, 1 illus.
- The "Homing Sense" of Terns—A Study of Animal Psychology at Tortugas Station, vol. II, No. 25, 167–172, 7 illus., 1 map.
- Producing High-Speed Protons and Tracing Their Paths, vol. II, No. 26, 175–178, 6 illus.; Notes on Institution Affairs: Conference of Archaeo-



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- logical Staff at Chichen Itzá, 179; Magnetic Observations in South America, 179-180; Swiftly Moving Nebulæ, 180; Searching for a "Lost World" of Plants, 180.
- Measuring Distances in the World of Stars, Pt. I—The Measuring Rods, by Dr. Walter S. Adams, vol. II, No. 27, 183-186, 5 illus.; Pt. II, A Flight Through Space, by Dr. Walter S. Adams, vol. II, No. 28, 187-191, 4 illus.; Notes on Institution Affairs; Astronomical Observatory Needed in Southern Hemisphere, by Dr. John C. Merriam, 191; On Radiating Surfaces, by Harold D. Babcock, 192.
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REPORT OF THE EXECUTIVE COMMITTEE



## REPORT OF THE EXECUTIVE COMMITTEE

*To the Trustees of the Carnegie Institution of Washington:*

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1932.

During this year the Executive Committee held eight meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 11, 1931, the members of the Executive Committee met and organized by the election of Mr. Pritchett as Chairman for 1932.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith. Particular attention has been given both by the Executive Committee and the Finance Committee to the question of loss of income due to existing economic conditions. Budget recommendations for next year are based upon opinion of the Executive Committee and the Finance Committee that reduction should be effected by cutting down general expense items in research projects and publication rather than by reduction of salaries.

The Board of Trustees, at its meeting of December 11, 1931, appointed Leslie, Banks and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1932. The report of the Auditor, including a balance-sheet showing assets and liabilities of the Institution on October 31, 1932, is submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

CARNEGIE INSTITUTION OF WASHINGTON

A vacancy exists in the membership of the Board of Trustees caused by the death of General Wm. Barclay Parsons on May 9, 1932. Nominations to fill this vacancy have been requested in accordance with provisions of the By-Laws, and such nominations will be submitted to the Board at its annual meeting on December 9, 1932.

Tenures of office of Cass Gilbert and of Wm. Church Osborn as members of the Executive Committee terminate at the coming annual meeting. There is also a vacancy in the Executive Committee by reason of General Parson's death.

HENRY S. PRITCHETT, *Chairman*

FREDERIC A. DELANO

CASS GILBERT

JOHN C. MERRIAM

WM. CHURCH OSBORN

STEWART PATON

ELIHU ROOT

*November 10, 1932.*

*Aggregate Receipts and Disbursements From Organization, January 28, 1902, to October 31, 1932*

RECEIPTS		DISBURSEMENTS	
<i>Interest from—</i>		<i>Investment.....</i>	<i>.....(*)</i>
<i>Securities and Bank Balances.....</i>	\$34,050,087.66		\$47,942,522.55
<i>Colburn Fund.....</i>	52,015.74	<i>Pension Fund.....</i>	524,484.29
<i>Sales of Publications.....</i>	307,024.47	<i>Insurance.....</i>	87,220.89
<i>Reversions.....</i>	570,001.60	<i>General Contingent Fund.....</i>	65,819.43
<i>Pension Fund.....</i>	57,550.66	<i>Special Emergency Reserve Fund.....</i>	121,153.24
<i>Insurance Fund.....</i>	10,155.22	<i>Special Reserve Fund for Administration Bldg. Additions.....</i>	894.88
<i>Special Reserve Fund (Rentals).....</i>	4,464.50	<i>Grants</i>	
		<i>Large.....</i>	\$23,052,179.48
		<i>Minor.....</i>	4,190,148.01
<i>Redemption and Sale of Securities.....</i>	38,002,271.21	<i>Publication.....</i>	2,022,402.06
<i>Carnegie Corporation of N. Y.....</i>	7,074,281.24	<i>National Research Council.....</i>	150,000.00
<i>Miscellaneous.....</i>	6,684.96	<i>Administration.....</i>	1,678,723.08
	80,134,537.26	<i>Cash in Banks, Oct. 31, 1932..</i>	79,835,547.91
			298,989.35
			80,134,537.26

(\*) Including Administration Building, \$309,915.69, and Collection Charges.





## REPORT OF AUDITORS

*November 25, 1932*

TO THE BOARD OF TRUSTEES,  
*Carnegie Institution of Washington,*  
*Washington, D. C.*

DEAR SIRs:

We have audited the accounts of the Carnegie Institution of Washington for the fiscal year ended October 31, 1932.

The Investments are shown on the Balance Sheet at cost and all Income has been accounted for. Appropriations and allotments were checked with certified copies of the Minutes of the Institution.

All Investments were verified by certificate from Guaranty Trust Company of New York except those registered as to income which, we are advised, were examined and checked by the Trustees in custody thereof.

The Cash in banks was confirmed by the Depositories and the Cash on hand by actual count.

Real Estate and Equipment are carried at cost.

The books of the various departments are audited by the Bursar, and we have included his figures in the annexed Balance Sheet without examination by us.

We hereby certify that, in our opinion, the Balance Sheet annexed hereto correctly states the financial condition of the Institution at October 31, 1932.

Very truly yours,  
LESLIE, BANKS AND COMPANY,  
*Accountants.*

Copies of the Financial Statement, certified by the auditor in the above report, follow on pages 68 to 73.

*Balance Sheet, October 31, 1932*

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REPORT OF AUDITORS

RECEIPTS		DISBURSEMENTS	
<i>Interest from</i>		<i>Investment</i>	
Securities.....	\$1,704,040.51	Securities.....	\$1,203,082.09
Bank Balances.....	3,125.47	Accrued Interest.....	11,239.34
<i>Sales of Publications</i>		<i>Pension Fund.</i>	
Index Medicus.....	119.35		59,637.68
Year Book.....	80.60	<i>Insurance Fund.</i>	
Miscellaneous Books.....	5,086.28		5,020.38
<i>Reimbursements—</i>		<i>General Contingent Fund.</i>	
Large Grants—			5,537.23
Departments.....	2,745.91	<i>Special Emergency Reserve Fund.</i>	
Contributions—			9.43
National Academy.....	1,500.00	<i>Special Reserve Fund for Administration Building Additions.</i>	
California Institute Technology.....	12,599.88		612.93
Bloodgood Cancer Research.....	500.00	<i>Grants</i>	
W. J. Salmon.....	380.00	Large.....	1,320,697.90
H. S. Shaw.....	2,500.00	Minor.....	189,381.72
<i>Minor Grants</i>		<i>Publication</i>	
Publications.....	20,225.79	General Publication.....	90,004.26
Administration.....	1,040.11	Catalogues, Calendars, etc.....	1,083.45
Unappropriated Fund.....	1,613.26	Shipping expenses.....	8,048.73
	1,880.14	Division of Publications.....	26,784.61
	545.11	<i>Administration</i>	
<i>Pension Fund</i>		Trustees.....	2,766.59
		Executive Committee.....	3,413.91
<i>Insurance Fund</i>		Salaries.....	48,499.92
		Surety, post, tel. & tel.....	2,329.82
<i>Special Reserve Fund (Rentals)</i>		Printing, Paper.....	1,315.05
		Office expenses.....	6,429.94
<i>Redemption and Sale of Securities</i>		Equipment.....	124.45
		Building maintenance.....	5,517.15
		Lectures and Exhibits.....	3,501.88
			73,898.71
<i>Carnegie Corporation of N. Y.</i>		<i>Cash in Banks</i>	
		Uninvested Principal—	2,995,038.46
		Awaiting investment.....	1,080.01
		Reserved for current needs.....	21,748.81
<i>Cash in Banks, Oct. 31, 1931</i>			22,828.82
			276,160.53
			298,989.35
			3,294,027.81

## CARNEGIE INSTITUTION OF WASHINGTON

### Schedule of Securities

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Railways</i>					
\$500,000	A. T. & S. Fe. 1st & ref. 4½s.			1962	M-S	\$498,750.
43,000	conv. 4s.			1955	J-D	39,022.50
50,000	A. T. and S. Fe. gen. 4s.	*		1995	A-O	50,056.25
150,000	B. and O. R. R. gen. and ref. 5s (\$100,000 fully registered)	*		1995	J-D	153,625.
200,000	Boston & Maine 1st 5s.			1967	M-S	195,812.50
100,000	Canadian National Ry. Co. 5s.			1969	J-J	98,500.
100,000	4½s.			1956	F-A	98,000.
160,000	Canadian Pac. Col. Trust 5s.			1954	J-D	159,710.07
50,000	Canada So. con. 5s.		*	1962	A-O	49,021.50
175,000	Ches. & Ohio gen. 4½s.			1992	M-S	174,062.50
75,000	Ches. and Ohio Ry. ref. and imp. 4½s. Series A.			1993	A-O	72,625.
100,000	B.			1995	J-J	98,250.
100,000	Ches. & O. R. R., Eq. Tr., Series 1929			1967	M-N	99,225.50
50,000	Cent. Pac. Ry. 1st ref. 4s.	*		1949	F-A	48,250.00
180,000	Chicago B. & Q. R. R. gen. 4s.			1958	M-S	169,501.25
200,000	Chicago B. and Q. Ill. Div. 4s.			1949	J-J	200,000.
35,000	Chicago M. St. P. & P. 5s.			1975	F-A	31,853.50
189,000	Chicago, Ind. & L. 1st & gen. 5s.			1966	M-N	189,461.25
140,000	Chicago M. St. P. & P. conv. adj. 5s.			2000	A-O	127,414.50
234,000	Chicago M. and St. P. Ry. gen. 4½s (\$50,000 fully registered)	*		1989	J-J	227,162.50
120,000	Chicago and N. W. Ry. gen. 3½s.	*		1987	FMAN	100,300.
200,000	Chicago & N. W. R. R. gen. 4½s.			1987	M-N	210,000.
300,000	Chicago, R. I. & P. Ry. 4½s.			1952	M-S	282,362.50
100,000	Chicago U. Station 6½s.			1963	J-J	114,266.50
100,000	Clev. C. C. & St. L. Ry., ref. and imp. 4½s.			1977	J-J	99,272.50
50,000	Clev. U. Term. 1st sink. 5½s.			1972	A-O	51,612.50
250,000	Elgin J. & E. Ry. Eq. 5s.	*			J-J	250,000.
240,000	6s.	*			A-O	240,000.
300,000	Erie R. R. gen. 4s.			1996	J-J	242,937.50
69,000	Gt. Nor. 1st ref. 4½s.	*		1961	J-J	69,053.25
125,000	Gt. Nor. Ry. gen. 4½s.			1977	J-J	122,656.25
165,000	5s.			1973	J-J	174,712.50
300,000	Ill. Cent. R. R., Joint 5s.			1963	J-D	311,291.50
121,000	Ill. Cent. R. R. ref. 4s.	*		1955	M-N	108,677.50
220,000	Ill. Cent. Eq., Trust, 4½s.			1965	A-O	211,687.79
200,000	Kan. City Term. 1st 4s.			1960	J-J	179,728.76
200,000	Kan. City, F. S. & M. Ry. ref. 4s.			1936	A-O	187,250.
325,000	Lehigh and L. E. 4½s.	*		1957	M-S	331,568.30
100,000	Lehigh V. H. Term. Ry. 1st 5s.			1954	F-A	104,750.
50,000	Long Island ref. 4s.	*		1949	M-S	48,285.
250,000	Louisville & N. R. R. 1st & ref. 4½s.			2003	A-O	249,125.
200,000	Mo. Kan. & T. 1st 4s.		*	1990	J-D	165,206.26
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s.			1977	M-S	212,762.50
200,000	Mo. Pac. R. R., Eq. Trust 4½s.				M-N	192,206.79
150,000	Mobile and O. R. R., ref. and imp. 4½s.			1977	M-S	145,750.
55,000	Morris & Essex R. R. Co., Construction Mtg. 4½s.			1955	M-N	52,937.50
175,000	N. Y. Cent. R. R. ref. & imp. 5s.			2013	A-O	186,906.25
50,000	N. Y. W. and Boston 1st 4½s.	*		1946	J-J	49,187.50
70,000	Norfolk & W. Joint 4s.			1941	J-D	64,925.
100,000	Nor. Pac. ref. and imp. 6s.			2047	J-J	102,187.50
50,000	" " gen. lien 3s.	*		2047	FMAN	33,101.25
51,000	Ore. Short Line con. 5s.		*	1946	J-J	49,883.25
310,000	Ore. Wash. R. & N. 1st ref. 4s (\$50,000 fully registered)	*		1961	J-J	274,272.50
80,000	Pa. R. R. Co. gen. 4½s.	*		1965	J-D	80,900.00
125,000	" " con. 4½s.	*		1960	F-A	130,703.13
100,000	Pitts. C. C. & St. L. 5s.		*	1975	A-O	99,637.50
42,000	Pitts. Shawmut & Nor. 4s.			1952		4,200.
100,000	So. Pac. 1st ref. 4s.	*		1955	J-J	92,148.75
100,000	So. Pac. S. F. Ter. 4s.			1950	A-O	100,000.
200,000	So. Pac. convertible 4½s.			1969	M-N	180,000.
350,000	So. Rwy. Co. 1st con. 5s.		*	1994	J-J	362,531.25
45,000	St. Paul Union D. 1st & ref. 5s.			1972	J-J	48,150.
225,000	St. Louis-S. F., prior lien 4s.			1950	J-J	203,431.25
230,000	Term. R. R. Assn. 4s.		*	1953	J-J	208,984.25
210,000	Texas & Pac. R. R., gen. and ref. 5s.	*		1977	A-O	213,882.50
2,084,000	Union R. R. deb. 6s.	*		1946	J-D	2,084,000.
140,000	Union Pac. 1st lien and ref. 4s.			2008	M-S	128,722.50
150,000	Union Pac. R. R. 4s.			1968	J-D	133,031.25
200,000	Va. Ry. Co. 1st 5s.		*	1962	M-N	206,535.50
200,000	Wabash Ry., ref. and gen. 5s.			1976	F-A	203,250.
200,000	Western Md. R. R. 1st 4s.	*		1952	A-O	162,100.
62,000	Wash. Term. Co. 1st 3½s (\$25,000 fully registered)	*		1945	F-A	53,728.75
13,083,000	Railway Sub-Total.					12,692,704.10



# REPORT OF AUDITORS

## Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility</i>					
\$200,000	Ala. Power Co. 1st ref. 5s.		*	1951	J-D	\$197,250.
100,000	Ala. Power Co. 1st ref. 5s.		*	1968	M-S	99,656.25
125,000	Am. Tel. & Tel. Co. sink. deb. 5½s.		*	1943	M-N	130,260.62
220,000	Am. Tel. & Tel. Co. deb. 5s.		*	1960	J-J	225,866.67
310,000	"			1965	F-A	311,012.50
300,000	Appalachian Electric & Power Co. 1st ref. 5s.		*	1956	M-N	296,125.
300,000	Ark. P. & L. Co. 5s.			1956	A-O	292,312.50
250,000	Bell Tel. Co. of Canada 1st 5s.			1955	M-S	257,656.25
100,000	"			1957	J-D	101,125.
300,000	Birmingham E. Co., 1st ref. 4½s.			1968	M-S	283,056.25
75,000	Blackstone Valley Gas & E. 5s.			1952	A-O	70,781.25
75,000	Brooklyn Edison Co., gen. mtg. 5s.			1952	J-J	72,562.50
300,000	Carolina Power & L. Co. ref. 5s.		*	1956	A-O	302,298.75
210,000	Cedar R. Mfg. & P. Co. 1st sink. 5s.		*	1953	J-J	209,107.04
300,000	Cincinnati Gas & E. 1st 4s.			1968	A-O	268,105.75
380,000	Columbia Gas and Elec. Corp., deb. 5s.			1961	J-J	379,762.50
300,000	Columbus Rwy., P. & L. 4½s.			1957	J-J	285,862.50
40,000	Comm. Edison 1st coll. 5s.			1954	J-D	42,000.
100,000	" " " 4½s.			1956	A-O	98,508.25
48,000	" " " Mtg. 4s.			1981	M-S	37,940.49
35,000	" " " 4½s.			1957	J-J	29,855.
60,000	" " " 5½s.			1962	J-D	55,650.
60,000	Consolidated Gas Co. of N. Y. deb. 5s.			1957	J-J	56,250.
50,000	Consumers P. Co. 1st ref. 5s.			1936	J-J	47,691.
100,000	Detroit Edison gen. ref. 5s.			1955	J-D	99,942.50
150,000	Detroit Edison gen. ref. 5s.			1962	F-A	155,825.
41,000	Duquesne Light Co. 1st mtg. 4½s.			1957	M-S	38,745.
325,000	Ga. Power Co. 1st ref. 5s.			1967	M-S	320,112.50
300,000	Gatineau Power, 1st 5s.			1956	J-D	298,750.
100,000	Gulf States Util. Co. 1st 5s.			1956	M-S	94,537.50
100,000	" " " 4½s.			1961	J-D	94,250.
100,000	Houston Ltg. & Power Co. 1st lien & ref. 4½s.			1981	D-J	98,375.
100,000	Idaho P. Co. 5s.			1947	J-J	100,750.
200,000	Illinois P. & L., 1st & ref. 5s.			1956	J-D	196,750.
200,000	Indianapolis P. & L. 1st 5s.			1957	J-J	198,806.25
200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s.			1955	M-S	202,182.50
300,000	Inter. Tel. & Tel. deb. 4½s.			1952	J-J	288,250.
280,000	Int. Rap. Trans. ref. 5s.		*	1966	J-J	276,701.
43,000	Kan. City P. & L. 1st 4½s.			1961	F-A	39,085.
30,000	Louisville G. & L. 1st & ref. 5s.			1952	M-N	28,875.
300,000	Memphis P. & L. 1st & ref. 4½s.			1978	A-O	279,250.
300,000	Milwaukee E. R. & L. ref. & 1st 5s.			1961	J-D	302,337.50
100,000	Minn. P. & L. 1st & ref. 4½s.			1978	M-N	92,156.25
109,500	Narragansett E. Co. 1st 5s.			1957	J-J	109,288.47
52,000	N. Eng. Tel & Tel 5s.		*	1952	J-D	51,748.
100,000	New Orleans Pub. S. 5s.			1955	J-D	99,200.
50,000	N. Y. Edison 1st ref. 6½s.		*	1941	A-O	55,573.75
42,000	N. Y. Gas. E. L. H. P. pur. mon. 4s.			1949	F-A	34,620.50
300,000	New York P. & L., 1st 4½s.			1967	A-O	286,125.
60,000	Niagara Falls P. 1st & con. 5s.			1959	J-J	61,800.
300,000	Northern Ind. Pub. S., 1st ref. 5s.			1966	M-N	305,775.
100,000	Northern States P. 1st ref. 5s.			1941	A-O	99,709.50
200,000	No. States Power Co., Inter. Ctf. 4½s.			1961	A-O	195,000.
300,000	Ohio Power Co., 1st and ref. 4½s.			1956	J-D	280,181.25
200,000	Okla. G. & E. 1st 5s.			1950	M-S	200,000.
200,000	Pac. G. & E. Co. gen. & ref. 5s (\$100,000 registered)		*	1942	J-J	197,185.53
25,000	Pac. Tel. & Tel. 5s.			1952	M-N	26,187.50
300,000	Penn. Power & L. Co., 1st mtg. 4½s.			1981	A-O	289,562.50
65,000	Penn. W. & P. 1st ref. 4½s.			1968	M-S	63,212.50
350,000	Phila. E. Co. 1st & ref. 4½s.			1967	M-N	351,733.01
135,000	Pub. Serv. of No. Ill., 1st ref. 5s.			1956	A-O	138,912.50
216,000	" " E. & G. 1st & ref. 4½s.			1970	F-A	209,635.
60,000	Puget Sound Power & Ltg. 1st & ref. 4½s.			1950	J-D	56,550.00
40,000	" " " 5½s.			1949	J-D	26,625.
30,000	Rochester Rwy. & Ltg. 5s.			1954	J-J	26,550.
75,000	Rochester Gas & Elec. Corp. gen. 5s.			1962	M-S	69,475.
100,000	Safe Harbor Water P. Corp. 1st 4½s.			1979	J-D	97,256.25
50,000	San Francisco, Hetch Hetchy Bond, 5½s.			1960	J-D	53,523.34
200,000	San Joaquin L. & P. Corp., ref. 5s.			1957	J-J	201,968.75
300,000	Shawinigan W. & P. Corp., 1st & coll. 4½s.			1967	A-O	286,212.50
50,000	So. Bell Tel. & Tel. 1st sink. 5s.			1941	J-J	47,687.50
250,000	So. Calif. Edison Co., ref. 5s.			1952	M-S	256,214.58
50,000	So. Calif. Tel. Co. 1st ref. sink. 5s.			1947	M-N	46,000.
200,000	So. Pub. Util. Co. 5s.			1943	J-J	200,000.
30,000	Syracuse Lighting Co. 1st and ref. 5s.			1957	J-J	28,912.50
125,000	Tenn. E. & P. 1st and ref. 5s.			1956	J-D	127,037.50
300,000	Texas Electric Service, 5s.			1960	J-J	292,700.
223,000	Union Elec. Light & Power Co. 5s.			1967	F-A	225,455.
220,000	Utah L. & T. Co., ref. 5s.			1944	A-O	215,193.
300,000	Va. E. & P. Co. 1st and ref. 5s.			1955	A-O	301,606.25
260,000	Washington Water Power Co., 1st and gen. mtg. 5s.			1960	J-J	262,762.50
13,474,500	Public Utility Sub-Total					13,233,556.75

# CARNEGIE INSTITUTION OF WASHINGTON

## Schedule of Securities—Continued

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
<i>Mortgages</i>						
\$25,000	Empire Title and Guarantee Co., Guaranteed 1st Mortgage Ctf. No. 278 5½%	*	.....	1934	M-S	\$25,000.
100,000	Lawyers Mtg. Co. Guaranteed 1st Mtg. Cts., Series 18397 5½%	*	.....	1935	J-J	100,000.
80,000	Lawyers Title and Guaranty Co., 5½%	*	.....	1935	A-O	80,000.
100,000	Mortgage—1184 Cromwell Ave., N. Y. 5½%	*	.....	1932	M-S	99,500.
100,000	1st Mtg. N. W. cor. Westbury Ct. & Flatbush Ave., Brooklyn 5½%	*	.....	1933	M-N	100,000.
100,000	Mortgage-Bond Co. of N. Y. 5s	*	.....	1938	J-D	96,000.
90,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. Ctf., 5½%	*	.....	1938	A-O	90,000.
100,000	N. Y. Title & Mtg. Co. 1st 5½s	*	.....	1933	J-J	100,000.
100,000	Title Guarantee and Trust Co. 1st Mtg. Ctf. 130057 5s	*	.....	1937	J-D	100,000.
795,000						790,500.
<i>Industrial</i>						
197,000	Aluminum Co. of A. 1st sink. deb. 5s	.....	.....	1952	M-S	198,057.49
50,000	American Radiator Co., deb. 4½s	.....	.....	1947	M-N	49,125.
105,000	Genl. Motors Acc. Corp. sink. 6s	.....	.....	1937	F-A	105,186.31
205,000	Gulf Oil Corp., sink. deb. 5s	.....	.....	1947	F-A	207,531.75
15,000	Humble Oil & Ref. Co., deb. 5s	.....	.....	1937	A-O	15,000.
110,000	Lacka. Steel conv. 1st 5s	.....	.....	1950	M-S	112,925.
110,000	Liggett & Myers 7s	.....	.....	1944	A-O	130,058.77
110,000	Lorillard Co. 7s	.....	.....	1944	A-O	128,614.75
94,000	Midvale S. & O. conv. 5s	.....	.....	1936	M-S	94,205.
8,000	Park & T. Co. sink. deb. 6s	.....	.....	1936	J-D	6,400.
200,000	Rwy. Express Agency, 5s	.....	.....	.....	M-S	200,000.
327,000	Stand. Oil N. Y. deb. 4½s	.....	.....	.....	.....	314,926.98
2,129,000	Tenn. C. I. & R. Co. 5s	.....	.....	1951	J-J	2,129,000.
50,000	Tex. Corp., Sinking deb. 5s	.....	.....	1944	A-O	49,125.
150,000	Youngstown S. & Tube 1st sink. 5s	.....	.....	1978	J-J	150,637.50
50,000	" " " " " "	.....	.....	1970	A-O	30,250.
3,910,000	<i>Industrial Sub-Total</i>	.....	.....	.....	.....	3,921,043.55
<i>Foreign</i>						
180,500	German External Loan of 1924 7s	.....	.....	1949	A-O	192,840.72
100,000	Govt. of Argentina 6s	.....	.....	1960	M-S	97,625.
115,000	Imp. Japanese Govt. 5½s	.....	.....	1965	M-N	103,212.50
300,000	Kingdom of Denmark, ext. 4½s	.....	.....	1962	A-O	274,375.
25,000	City of Montreal 5s	.....	.....	1956	M-N	24,062.50
75,000	City of Montreal sink. 5s	.....	.....	1954	M-N	72,375.
100,000	City of Montreal 4½s	.....	.....	1946	F-A	94,368.90
200,000	New South Wales, ext. 5s	.....	.....	1958	A-O	189,562.50
100,000	Province of Alberta deb. 4½s	.....	.....	1958	J-J	93,750.
100,000	Province of Alberta 5s	*	.....	1950	A-O	101,125.
100,000	Province of British Col., 4½s	.....	.....	1951	J-J	98,875.
100,000	Province of British Col. deb. 5s	.....	.....	1939	J-J	100,412.67
100,000	Province of British Col. deb. 5s	.....	.....	1954	A-O	99,000.
200,000	Province of Manitoba deb. 4½s	.....	.....	1958	A-O	190,515.70
100,000	Province of Nova Scotia 4½s	.....	.....	1952	M-S	100,312.50
100,000	Province of Ontario 4s	.....	.....	1964	M-N	87,150.10
60,000	Province of Ontario 5½s (\$25,000 registered)	*	.....	1937	J-J	61,291.10
100,000	Province of Ontario 5s	.....	.....	1959	M-N	99,789.63
40,000	Province of Ontario 6s	.....	.....	1943	M-S	43,137.50
30,000	Prov. of Saskatchewan deb. 5s	.....	.....	1943	J-D	30,627.44
75,000	Toronto Harbour Comm. 4½s	.....	.....	1953	M-S	72,062.50
100,000	City of Toronto con. deb. 5s	*	.....	1949	J-D	96,152.42
90,000	City of Toronto, 5s	.....	.....	1952	J-D	89,333.53
50,000	City of Winnipeg inter. deb. 5s	.....	.....	1943	J-D	48,250.
50,000	City of Winnipeg deb. 6s	.....	.....	1946	A-O	53,500.
100,000	City of Winnipeg deb. 4½s	.....	.....	1946	J-D	95,375.
2,690,500	<i>Foreign Sub-Total</i>	.....	.....	.....	.....	2,609,082.21
<i>Stocks</i>						
50,000	A. T. & S. Fe pref. stock	*	.....	.....	F-A	52,125.
200,000	Cons. Gas. Co. Cum. pref. stock	*	.....	.....	FMAN	198,725.
100,000	Du Pont de Nemours, deb. Stock	*	.....	.....	JAJO	116,125.
50,000	J. I. Case Thresh. M. Co. pref. stock	*	.....	.....	JAJO	62,225.
40,000	Union Pac. R. R., pref. stock	*	.....	.....	A-O	33,415.
500,000	U. S. Steel Corp., pref. stock	*	.....	.....	MJSD	715,173.50
940,000	<i>Stocks Sub-Total</i>	.....	.....	.....	.....	1,177,788.50
34,893,000	<i>Aggregate—Funds Invested</i>	.....	.....	.....	.....	34,424,675.11

# REPORT OF AUDITORS

## Real Estate and Equipment, Original Cost

<i>Administration (October 31, 1932)</i>			
<i>Washington, D. C.</i>			
Building, site, and equipment.....			\$403,155.09
<i>Division of Plant Biology (September 30, 1932)</i>			
<i>Palo Alto, California (Headquarters)</i>			
Buildings and ground.....	\$157,903.63		
Laboratory.....	45,180.56		
Library.....	20,933.35		
Operating appliances.....	22,620.73	246,638.27	
<i>Department of Embryology (September 30, 1932)</i>			
<i>Wolfe and Madison Sts., Baltimore, Md.</i>			
Library.....	2,824.79		
Laboratory.....	12,185.74		
Administration.....	6,552.03	21,562.56	
<i>Department of Genetics (September 30, 1932)</i>			
<i>Cold Spring Harbor, Long Island, N. Y.</i>			
Buildings, grounds, field.....	286,648.25		
Operating.....	25,352.74		
Laboratory apparatus.....	20,364.30		
Library.....	36,925.84		
Archives.....	45,488.90	*414,780.03	
<i>Geophysical Laboratory (September 30, 1932)</i>			
<i>Upton St., Washington, D. C.</i>			
Building, library, operating appliances.....	211,764.22		
Laboratory apparatus.....	136,005.47		
Shop equipment.....	14,929.01	362,698.70	
<i>Division of Historical Research (September 30, 1932)</i>			
<i>Tower Building, Washington, D. C.</i>			
Operating.....	11,197.65		
Library.....	7,065.77	18,263.42	
<i>Tortugas Laboratory (Sept. 30, 1932)</i>			
<i>Tortugas, Florida</i>			
Vessels.....	30,930.43		
Buildings, docks, furniture, and library.....	12,130.86		
Apparatus and instruments.....	9,322.55	52,383.84	
<i>Department of Meridian Astrometry (September 30, 1932)</i>			
<i>Dudley Observatory, Albany, N. Y.</i>			
Apparatus and instruments.....	4,846.84		
Operating.....	5,070.42	9,917.26	
<i>Nutrition Laboratory (September 30, 1932)</i>			
<i>Vila St. Boston, Massachusetts</i>			
Building, office, and shop.....	131,449.08		
Laboratory apparatus.....	36,046.29	167,495.37	
<i>Mount Wilson Observatory (August 31, 1932)</i>			
<i>Pasadena, California</i>			
Buildings, grounds, road, and telephone line.....	202,474.64		
Shop equipment.....	45,834.44		
Instruments.....	659,494.04		
Furniture and operating appliances.....	194,524.96		
Hooker 100-inch reflector.....	604,840.09	1,707,168.17	
<i>Department of Terrestrial Magnetism (September 30, 1932)</i>			
<i>5241 Broad Branch Road, Washington, D. C.</i>			
Building, site, and office.....	215,659.52		
Survey equipment.....	94,306.60		
Instruments, laboratory, and shop equipment.....	159,581.	469,547.12	
		3,873,609.83	

\*Including Harriman Fund property in the amount \$183,671.75 shown as a separate item on the Balance Sheet.



## REPORTS ON INVESTIGATIONS





## DEPARTMENT OF EMBRYOLOGY<sup>1</sup>

GEORGE L. STREETER, DIRECTOR

The profound influence upon the proper functioning of the animal body which in the form of hormones emanates from the glands of internal secretion needs no emphasis here. It may be pointed out, however, that the physiology of reproduction is no exception to hormone domination. Every step in the development of a new individual from the maturation of the egg to the birth of the fetus is largely at the mercy of the interplay of hormonal reactions. Under these circumstances it is obvious that in its researches our laboratory must concern itself with the activities of the endocrine glands.

It is particularly the anterior lobe of the hypophysis and the ovary that jointly regulate the generative tract. It will be told in this report how experimental animals are being studied in which one or the other or both of the glands have been eliminated by surgical removal and how in some degree reparation can be made by use of extracts or transplantation of similar tissues from other animals. Experiments on ovarian stimulation will also be referred to in which a similar result can be obtained from the use of hypophysis material and from the urine of pregnant women, and it will be shown that these are entirely different substances. The one is always active regardless of pregnancy and it makes little difference from what animal it is taken, whereas, the other is an excretion product which seems to arise from the chemical mechanism of human pregnancy. This is of importance in throwing further light on the nature of hormones and emphasizes the need of more accurate requirements in the isolation of individual hormones. There has been confusion between hormones and hormonal effects, and what were thought to be separate hormones have been found in some instances to be no more than a difference in dosage or manner of administration. The designation "hormone" is a physiological term rather than a chemical one. It is concerned with effects rather than with composition and so has not yet attained the preciseness that exists in case of the alkaloids, for instance. Conservatism is therefore necessary in this general field. We are fortunate in being able to solve some of the hormone problems in a form as close to man as the monkey.

Our facilities for experiment and observation on monkeys have recently been greatly improved. An additional story designed for our purposes, consisting of laboratory rooms and open air paddocks, was erected on our present building by the Johns Hopkins University, and the colony was moved into its new home in December of the past year. Through this generous cooperation on the part of the University, we now have comfortable space and sufficient separation for an experimental colony of 200 animals. In the design of these new quarters the architects had the advantage of our several years' experience in handling the macaque and so were able to provide for us what seem to be ideal conditions for experimental studies and a maximum simplicity in arrangements for the daily care of the animals. The following report will reveal what an important part the colony is playing in our embryological investigations and in our studies on the physiology of repro-

<sup>1</sup> Address: Wolfe and Madison Streets, Baltimore, Maryland.

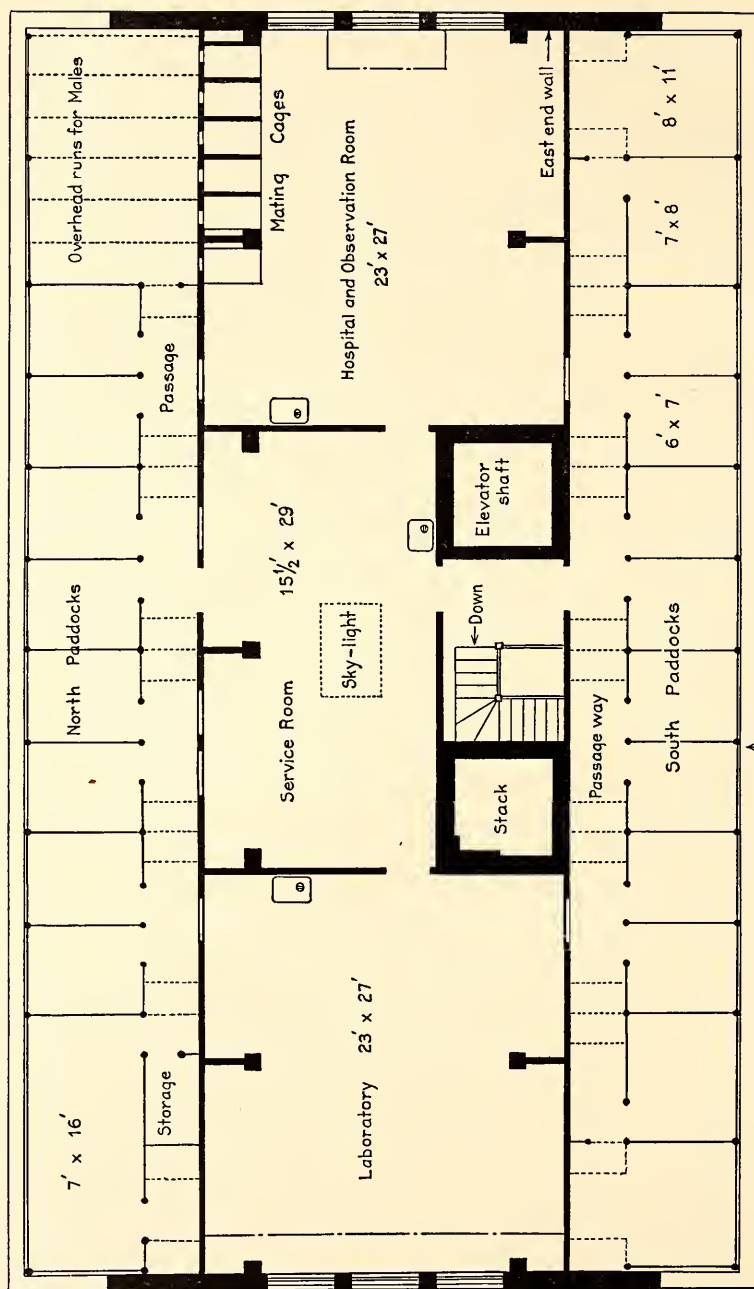


FIG. 1.—Floor-plan of new quarters for monkey colony, recently erected on top of our laboratory building. Hutches shown by dotted lines.

duction, and it will therefore be readily understood why careful thought has been given to the improvement of the details underlying its maintenance.

During the past year, as will presently be seen, several important contributions have been made concerning the structure and physiology of the cell. New details have been observed in the character of chromosome movements during mitosis, both in normal and abnormal divisions. Early splitting of the chromosomes has been found characteristic of malignant cells. For the first time elimination of whole chromosomes has been demonstrated, showing that these supposedly indispensable bearers of the genes may thus be

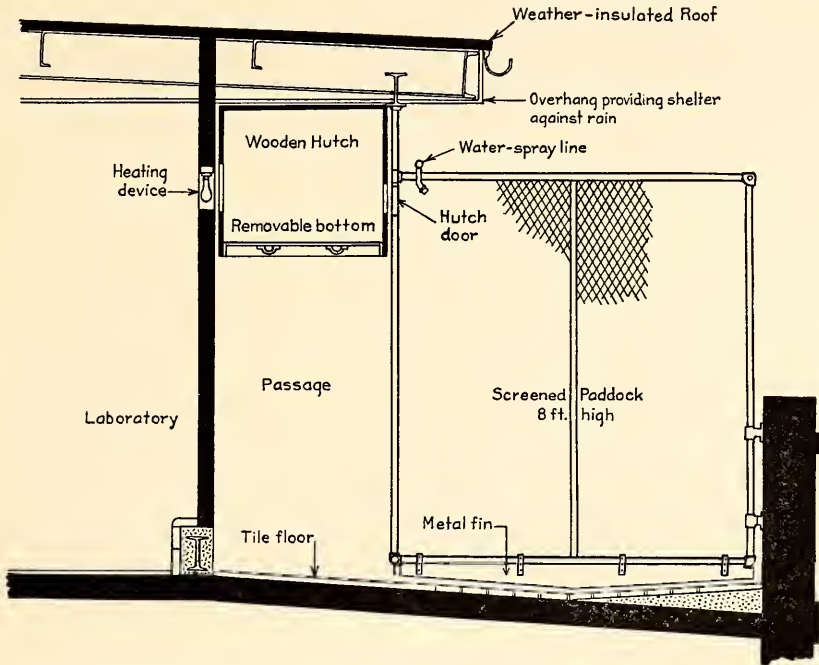


FIG. 2—Section through a typical paddock, showing how animals can stay in open air and sunshine or retire into a protected overhead hutch. A water-spray adds to comfort of animals during hot weather and electric bulbs afford warmth in winter. Perspective sketch shown on next page.

spared. Observations have been made relative to the part played by chromosomes in sex-determination. The relation of viruses to cells has been studied and a virus chemically free of protein was obtained which was still capable of producing a tumor. Further observations have been made regarding the nature of specific susceptibility of tissue cells in tuberculosis, proving that the hypersensitivity resides in the cells themselves and is not due to allergic plasma.

In the domain of the nervous system, a study has been made of the brain of the porpoise. Further accomplishments are to be credited to Dr. Lewis H. Weed's studies of the cerebrospinal fluid. Greater accuracy has been reached in determining the pressure alterations that occur on change in body



posture. By means of the ratio that has been found to exist between fluid-dislocation and pressure-change, it is now possible to determine precisely the diminution of the volume of the brain and of the cerebrospinal fluid induced by the use of intravenous hypertonic solutions. Further evidence has been found of the non-existence of sympathetic trophic nerves. However, atrophy of muscle fibers occurs where there is a motor lesion and the degeneration that follows is indicative of the close structural and functional continuity that exists between the nervous and the contractile elements of muscle. Detailed studies have been made of nerve endings and it has been

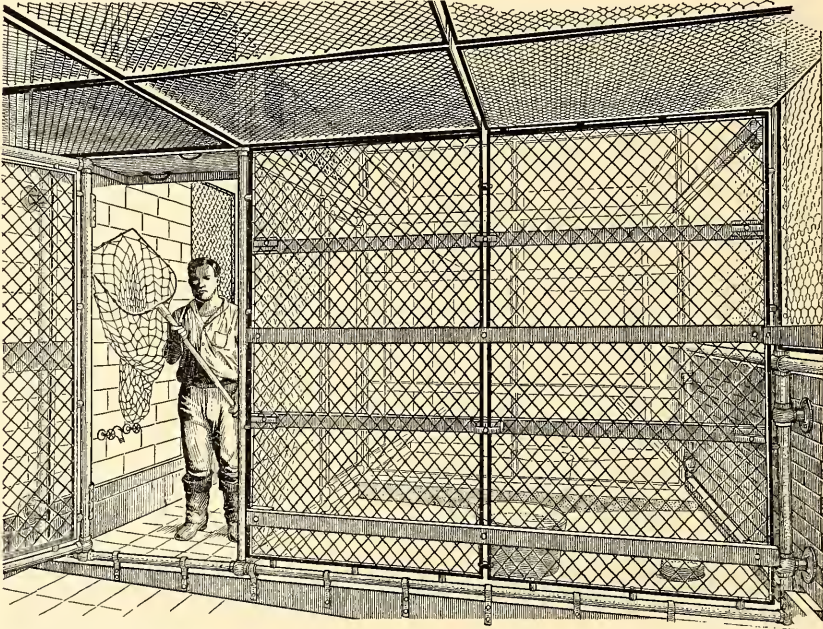


FIG. 3—Sketch showing character of paddocks. Perches are designed for cleanliness and so as to offer no hindrance to netting of animals. Paddock shown is below runways for males. All others are a little higher and allow entrance into hutches, one of which can be seen above caretaker. Partitions are fitted to sloping floor by metal fins. Floors and passage-ways are a continuous surface of tile, drained and easily hosed.

shown that higher mammals have a single uniform neuromotor unit in their limb muscles, between which and the sympathetic vascular innervation there are no communications. Regeneration in sympathetic nerves has been studied in the limbs for the first time. This was made possible by a new test of functional response. In a study of the cutaneous end organs of tactile sense, it has been found that a diminution of excitability occurs on local interference with blood circulation, such as is brought about by pressure on the skin. This phenomenon had been previously supposed to be due to other causes.

Some of the investigations reported in the following pages are in the nature of side-lights on the development and evolution as revealed by compar-



ative anatomy. These include the facial muscles, muscles of the foot, muscle groups associated with the shoulder and pelvic girdles, muscles of the chest wall and the tendency to a reduction of the human thorax toward eleven pairs of ribs. The density of hair has been studied at different stages of growth and in different types of primates. A study has also been made of the hereditary tendency among primates toward elimination of the upper lateral incisor teeth. Completeness of the tracheal rings has been found to have less group-constancy than heretofore supposed. A comparative study of the brachial flexor muscle group has been made for all primates. An aberrant anatomical character has been described in monotremes which in no sense can be regarded as leading toward the marsupialia and placentalia. Finally attention is called to an analysis that has been made of certain forms of blood vascular plexuses exhibiting convergent adaptation to extreme modes of life in the sloth, the loris and the four-toed ant-eater.

#### HUMAN AND COMPARATIVE EMBRYOGENESIS

The *Macacus rhesus* fortunately is just small enough and is of suitable build to enable the human finger to feel the posterior surface of the uterus and the ovaries through the rectal canal. When Dr. C. G. Hartman discovered this he found that by daily examinations he could follow the changes in consistency and size of these organs. As the ovary with a developing follicle enlarges, he is prepared for its abrupt loss in size when the follicle ruptures and so knows to a day the time of ovulation. The animal can then be mated with a fair chance of a dated pregnancy taking place. Whether a pregnancy is actually under way can be verified at about the end of the second week, and somewhat earlier if an operative abdominal exploration is resorted to. With the advantage of this technique Dr. Hartman has been able to secure for the first time primate embryos of known ages, and studies of these are already under way. Further, the maternal areas where the embryos are implanted can be removed in the living state and under conditions that make perfect preservation possible. During the past year several of the desired stages have been secured and the way appears open to the making of a complete embryological study of this primate embryo during the significant period of the first three weeks, a period that must necessarily remain fragmentary in human material for a long time to come.

#### THE MACACUS RHESUS EMBRYO

The new embryological material referred to above is already yielding new facts concerning the processes of development. Dr. C. H. Heuser has found that the young blastocyst or chorionic sac soon after implantation temporarily clothes its lumen with an intrachorionic mesothelial membrane which walls off the embryo from the segmentation cavity. This membrane is clearly a derivative of the primitive mesoblast and serves to explain the nature of a similar formation in human embryos where it occurs in a less complete manner. As the embryo grows larger, the mesothelial membrane becomes gradually crowded toward the opposite wall. At the five-somite stage it traverses the middle of the chorion, still intact. Soon after that it becomes fenestrated and disappears. Thus far Dr. Heuser has arrived at no decision as to the function of this membrane.

The macaque material has greatly facilitated my own studies on the mechanism of implantation of the human ovum to which I have been giving my attention for several years. By comparison of the descriptions of all the known early human embryos and the study of the specimens in our own laboratory certain general facts become clear. First of all the ovum does not penetrate deeply into the endometrium, but lies just beneath the surface epithelium. As it enlarges it at once begins to bulge into the uterine cavity. Secondly, the reaction of the maternal tissues to the invading ovum is at first limited to the immediate vicinity, indicating that the ovum itself is responsible. And thirdly, there is a marked vascular reaction around the ovum resulting in large venous sinuses which spread around the ovum giving it an environment of stagnant blood. The hæmal environment is further added to by extravasations from capillaries produced by the erosive action of the embryonic trophoblast. The blood collects in the glands and the trophoblastic lacunæ, the latter being the precursors of the intervillous spaces. These same phenomena are now being studied in the macaque, in which work I have the assistance, as a collaborator, of Dr. G. B. Wislocki, of Harvard University, whose acquaintance with the problems of comparative implantation has been frequently remarked in these reports.

#### YOUNG SLOTH EMBRYOS

Four early stages of development of the sloth have been studied by Dr. G. B. Wislocki and Dr. C. H. Heuser, with special reference to their analogies to similar stages in man. Close relationship to man is shown in the character of the body stalk and its diminutive allantois, the amniotic sac and its relation to the body stalk, and the yolk sac. The latter exhibits a well-marked attachment to the opposite wall of the chorion, an attachment only occasionally present in man. In the older stages, as this attachment is lost, a pinched-off remnant of the yolk-sac process remains as a small cyst at the attachment site, apparently serving no purpose. Much remains to be learned regarding the functions of the yolk sac and allantois, and the morphogenic relations between body stalk and allantois. The chief method of determining the purposes of these structures appears to rest in their comparative embryology.

#### PATHOLOGY OF THE EMBRYO

One of the congenital deformities occurring in man and one that is marked with serious consequences is malformation of the esophagus, associated with a tracheo-esophageal fistula. This condition has been studied by Dr. A. H. Rosenthal, of the Mount Sinai Hospital, New York. Dr. Rosenthal had the opportunity of studying several specimens in which this maldevelopment had occurred. As a guest in this laboratory he also studied the embryological factors involved in its production. He showed that the constancy in the site of the fistula established it as an embryological defect of primitive nature and that it is concerned with that early period when the trachea is split off from the foregut. It lies at about the region where the notochord has its most caudal open communication with the entoderm. A defect at this critical point would be followed by incomplete differentiation of the trachea and esophagus with a consequent fistula. Such appears to be the underlying embryological explanation in Dr. Rosenthal's cases.

## CYTOLOGY AND STUDY OF TISSUE FLUIDS

## TISSUE CULTURES

The survey of various embryonic tissues with respect to the characteristics of their growth in artificial media has been continued for several years in this and other laboratories. During this past year brain cultures of embryo chicks have been studied by Dr. Peter Mihalik of the Anatomical Laboratory of Budapest. Dr. Mihalik's visit was made possible through a Rockefeller Fellowship which enabled him to spend the winter here, and apply his wide experience in the finer structure and development of nerve cells and nerve fibers to the culture of brain tissues. He found that in pieces of embryo chick brain that are replanted every two to four days there are three phases of growth. During the first two to five days the cultures are characterized by an outgrowth of nerve processes. This is followed by another period, from the fifth to the twelfth day, during which there is cell migration. Then, beginning from the sixth to the seventeenth day, there follows a period lasting indefinitely, during which there is a growth of an epithelial membrane. These phenomena vary somewhat with the age of the embryo, being retarded in younger embryos. The periods also overlap each other more or less.

A point of particular interest in Dr. Mihalik's observations was the identity of the migrating cells characteristic of the second period. He was able to demonstrate that they are macrophages and identical with the macrophages of other tissues. Such wandering cells had been regarded by other workers as microglia cells, but by the neutral red test he was able to show that microglia is quite a different nerve-tissue component.

The possibility of utilizing Kendall's formula as an improved medium for tissue cultures has been investigated by Mrs. M. R. Lewis and Dr. W. A. Nettleship. They made many tests with Kendall's medium which is a broth but is lacking in fats, peptone and protein degradation products. It also possesses the advantage that it can be supplied in dry form. Kendall's medium was designed for the cultivation of filterable viruses. They found that chick embryo tissue will grow in this medium for four days, and if the amount of dextrose is increased, cultures remain good for as long as ten days. It is, however, not as satisfactory either as to extent of growth or length of life of the cells as the Locke-Lewis solution, which we have heretofore employed. The Kendall medium would be suitable where viruses are cultivated and which need to be changed every four days. The tissue growth would be long enough under those conditions.

## LOCOMOTION OF THE LYMPHOCYTE

During the past year there was published in its final form the motion-picture study of migrating lymphocytes by Dr. W. H. Lewis, in which study he determined their detailed changes in structure and the physical mechanism of their locomotion. From that study I have taken the adjoining figure which illustrates the Lewis construction ring and also the continuous reversions from plasmagel to plasmasol and back again, by means of which locomotion is apparently accomplished.



Recently Dr. Lewis has made additional observations relative to the rate of migration. Using motion-picture records of lymphocytes in plasma cultures of lymph nodes of the rat, he found that in a 5½-hour culture the average rate of locomotion in the 45 cells studied was 19 microns per minute, the variation being between 11 and 32 microns. In a 24-hour culture the average rate was somewhat less, 16.6 microns per minute, and the variations were between 11.7 and 23.4 microns. These determinations are, of course, at a given temperature (39° C.). He finds that lymphocytes

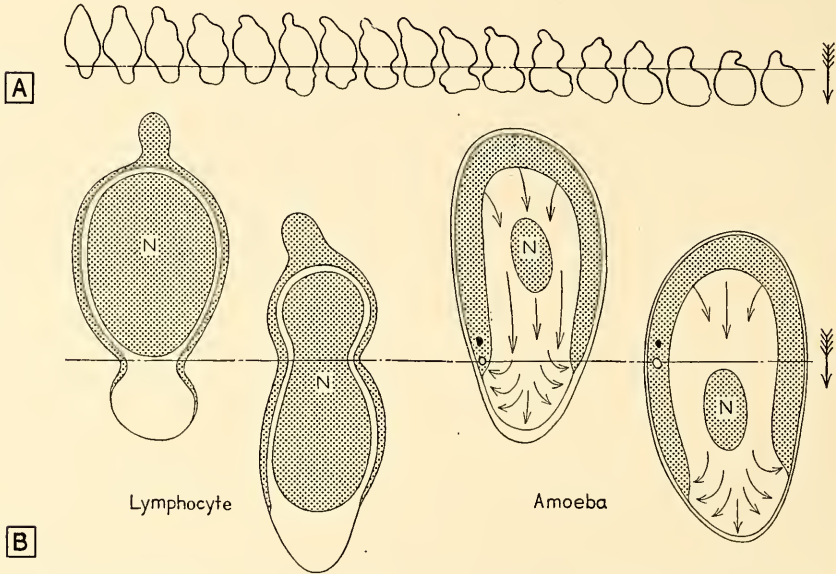


FIG. 4—A. Tracings of a lymphocyte made at 2.5-second intervals showing from left to right forward movement (down) of an individual cell; the constriction ring by moving backward retains a fixed position relative to environment.

B. Diagram showing essential likeness in locomotion of lymphocyte and amoeba. The relatively firm plasmagel shell undergoes continuous solution at its posterior end, blending with plasmasol center, and therewith flows forward, continuously reverting to firmer state and adding itself to advancing rim of plasmagel shell. In other words, relative to its state of gelation, it continuously turns itself inside out at advancing anterior pole. Cell nucleus (N), is relatively much larger in lymphocyte.

have alternate periods of rest and migration, varying from a few seconds to many minutes. Also during a migration period the rate of locomotion varies from moment to moment. During rapid periods the lymphocyte becomes elongated, during the less rapid periods it is shorter, and during the rest periods it is almost spherical. It is also to be noted that the antero-posterior axial polarity persists throughout a whole migrating period.

#### VIRUS STUDIES

Much activity has been directed in recent years to the study of virus diseases, that is, a group of diversified diseases having in common the char-

acteristic that the active agent which causes them is a material so fine that it will pass through the pores of extremely fine filters. These diseases have in each instance their own virus, and the viruses can be clearly separated one from another. The nature of these viruses, however, aside from their filterability, is unknown. Investigators have not been able to agree whether they are minute living organisms, possibly a more primitive form of life than we are acquainted with, or whether they are inanimate and perhaps products of cellular perversion capable of producing similar perversions in other cells.

Thus far it has been possible to obtain viruses only in the form of tissue extracts. Such extracts are complicated in their composition, containing proteins, enzymes, fats, carbohydrates, salts, and other substances as well as the specific disease-producing principle. Thus any step toward simplifying or purifying virus extracts leads nearer to a solution of the virus problem. Such steps have been made during the past year by Mrs. M. R. Lewis and her coworkers. By the use of collodion membranes, they have been able to obtain from chicken sarcoma filtrates that are free from protein, by chemical test, though still capable of producing a tumor. Being able to calculate the size of the pore of the membrane they were able to demonstrate that the size of the active agent particle that causes chicken tumor is less than 50 millimicrons, which is beyond the range of satisfactory visibility by any system of lenses that we now have. Mrs. Lewis has also been able to produce rabbit myxoma with virus in which the protein was removed by mixing it with 25 per cent of powdered animal charcoal, the technique being similar to that which she and W. Mendelsohn previously utilized in chicken tumors. Inoculation of charcoal-purified extracts of rabbit tumor produces tumors somewhat slower than portions of the same tumor extracts not purified. However, the later course of the disease is the same. The same lesions appear and the animal dies within a few days regardless of whether or not the protein has been removed from the extract.

Reference was made in my last report to Mrs. Lewis' observations on the effect of dyes on chicken tumor virus. She tested the action of 36 of the common biological dyes on extracts of chicken tumor and found five of them to have a marked inactivating effect. One of them (toluidin blue) inactivated the virus of chicken sarcoma in solutions of one part of dye to 10,000 parts of tumor extract. With the collaboration of Warren Reed Lewis, additional dyes have been tested by Mrs. Lewis and especially of the type of phenol indophenol. Two of this group proved to have the greatest inactivating effect. The dyes were also tested on extracts of infectious myxoma of the rabbit. The rabbit-myxoma virus proved much more potent than that of chicken tumor and could not be inactivated in as weak concentrations. However, the same dyes that were effective in one were also effective in the other. The concentrations of any of the dyes tested, necessary to render the virus inactive, are such that they can only be carried out in the test tube; such concentrations would not be possible in the living body. That is, no dye has yet been found that could be safely injected into the body in sufficient quantity to destroy a tumor-virus that might be present.



## MECHANISM OF ALLERGY

When a foreign protein is introduced into the tissues of the animal body certain changes take place that result in a hypersensitive reaction if that same protein is introduced again. A common form of reaction is spasmodic contraction of the vascular or bronchial muscle fibers as seen in hay fever. Another form includes cases where the repeated protein produces local damage of tissue accompanied by inflammation. It is this latter phenomenon that is spoken of as allergy. Thus allergy is an exaggerated specific susceptibility of the tissue cells. In a previous Year Book, I referred to the investigations of A. R. Rich and M. R. Lewis on allergy in tuberculosis and of their experiments which showed that the phenomenon is due to a change in the individual cells rendering them more sensitive to the products of the tubercle bacillus.

Since that time Dr. Rich and Mrs. Lewis have completed their study, insofar as tissue culture could render assistance, and have compared the mechanism of the inflammatory-tissue destroying reaction (allergy) with that of the musculo-spasmodic reaction (anaphylaxis), both consisting of a hypersensitivity to foreign proteins. The methods of tissue culture were particularly suitable for these studies. With this technique the free cells serve as delicate indicators of the presence of injurious substances and devoid of the complications of nervous and circulatory influences. It made it possible to answer affirmatively the question as to whether the cells can be damaged by the protein in the presence of a normal plasma. They thus proved that the hypersensitivity resides in the cells themselves and that it was not due to allergic plasma.

The exact nature of heightened susceptibility of allergic cells is left unanswered by them, but they regard it as probable that the change consists in the intimate attachment of antibody to the cells comparable to the fixation of antibody to smooth muscle cells, as is generally believed to underlie the condition of anaphylaxis. The antibody is presumably manufactured by the macrophage group of cells and is carried by the blood stream to the various cells of the body to become attached to them, and thereby rendering them hypersensitive. Dr. Rich and Mrs. Lewis have established an additional fact of importance in showing, as has also been shown for anaphylaxis, that it is not the free circulating antibody that is important but it is only that portion that is bound directly to the tissue cells that is necessary for the production of the immediate, local necrotic effects of allergy in tuberculosis.

## STAINING OF MUSCLE FIBRILS

Mention may be made here, though it concerns a different cytological field, of the staining experiments of Dr. Laurus Einarson, a guest in the Anatomical Laboratory and holder of a Rockefeller Fellowship. After trying many dyes for staining the fine fibrils in the tongue membrane of the frog, he succeeded in obtaining satisfactory results with a solution of naph-tazarin in pure acetone. With this treatment there is no overstaining and therefore differentiation is unnecessary. Nuclear counter staining can be had by previous staining with gallocyenin-chromalun.

## CHROMOSOME STUDIES

### MOVEMENTS OF CHROMOSOMES

By means of the motion-picture technique, Dr. W. H. Lewis has added to our knowledge of chromosomal behavior during mitosis and brings one step nearer an understanding of that thus far unexplicable phenomenon. He finds that during prophase the chromosomes actively shift in position relative to each other. This activity greatly increases as they become arranged in the median plate, in the metaphase stage. This lively shifting back and forth continues during metaphase but the chromosomes become passive as soon as they split and move toward the poles. The forces that effect their splitting appear to reside in or immediately about the chromosomes and the picture is not that of their being simply pulled apart by spindle fibers. In fact, in these living preparations no spindle fibers could be seen. The chromosomes remain completely inactive as the daughter nuclei are formed, and it is evident that the controlling forces have taken on another character.

During cleavage there occurs a rapid intake of fluid which is expressed by bleb formation, this apparently being a recovery from the dehydration and contraction that marks the earlier stages of mitosis. It will presently be seen that blebbing of cells occurs on exposure to ether vapor and that it is also associated with pseudopodial formation. The time periods of the different stages of division are: forty minutes for prophase; two to seven minutes for metaphase; and two to nine minutes for telophase.

Mitosis was observed by Dr. Lewis also in abnormal cells from rat sarcoma where there was tripolar division. Here the time intervals are somewhat longer, some cells in fact remaining in mitosis for long periods without dividing. In such instances the chromosomes continue to shift back and forth without succeeding in splitting. The chromosomal content of cells resulting from tripolar division varies considerably, an evidence of the abnormal state of these cells.

### EARLY SPLITTING OF CHROMOSOMES IN TUMOR CELLS

In a study of sarcoma and carcinoma tumor cells cultured artificially, Mrs. M. R. Lewis has found a definite visible splitting of the chromosomes during the early phases of division, in fact from their earliest appearance. This occurs both where there are the normal number and where they are greatly increased. This appears to be one characteristic that is common to most tumors. There are other characteristics that have been observed for individual tumors and that follow in successive transplants. These include size and granular nature of the nucleus, size and number of nucleoli, and the number and behavior of the chromosomes. Such characteristics, however, have been found to be limited to a particular strain of tumor. It is therefore of special interest that Mrs. Lewis has found early marked splitting of the chromosome to be common to all malignant cells in her cultures.

### ACTION OF ETHER ON LIVING CHROMOSOMES

By exposing living cells to small quantities of ether or ammonia vapor, Dr. M. Rosenfeld has been able to induce abnormal cell division and follow in tissue cultures under the microscope the atypical behavior of the chromo-

somes and other parts of the cell. This is one of those borderland studies, partly pharmacological and partly cytological. It not only throws light on the behavior of chromosomes under the conditions of the experiment but also is of some importance in revealing the action of such vapors upon living tissues. Using fibroblasts of five- to nine-day old chick embryos he made hanging drop cultures in chambers to which ether or ammonia vapor could be administered in desired amounts and the changes in the character and behavior of the cells followed under the eye. The change of most interest was in the alteration in the mitotic process which could be interrupted at the metaphase or anaphase and the nucleus made to return to a normal-looking single resting stage.

If ether is administered while the chromosomes are undergoing division, they become clumped into one or more masses, according to the stage of mitosis, and when replaced in a normal medium they disperse in the form of a single nucleus. If it were an anaphase cell there would, presumably, arise a nucleus with a tetraploid number of chromosomes. The immediate effect of etherization of tissue culture cells is a reversible fluidification of the cytoplasm which is evidenced by blebbing, formation of granular processes and amoeboid deformation. Whether the fluidification was due to a gel-sol transformation, to fluid imbibition or to an increased permeability of the cell membrane could not be determined. Dr. Rosenfeld also immersed cultures in a series of ammonia buffer solutions and found that chromosomes become clumped in solutions having a pH 8.9 at 38° C. and in more alkaline buffers. Resting cells, however, remain unaffected until a pH 9.5 is reached. Many types of abnormal mitotic figures are found in cells treated in this way.

#### STUDYING CHROMOSOMES IN ENTIRE INSECT EGGS

By applying the Feulgen reaction for thymonucleic acid, Dr. C. W. Metz and Miss M. L. Schmuck have been able to stain the chromosomes in eggs of the fungus gnat in such a way that in the intact egg the deeply stained chromosomes can be clearly viewed, whereas the other components of the egg remain quite transparent. This eliminates the elaborate sectioning technique that heretofore was necessary. It also greatly facilitates the study of the chromosomes and, what is still more important, it adds to the accuracy with which their structure and relative position in the egg can be determined. The method has already been utilized to great advantage in Dr. Metz' studies, as will be seen in the following paragraphs.

#### CHROMOSOMES IN SCIARA

It had been previously shown by Dr. Metz and his coworkers that in *Sciara* the number of chromosomes in the germ-like cells that form the sex glands is always greater than in the cells that form other organs. During the past year Dr. A. M. DuBois has determined at what period in development this difference in chromosome number is established. She has found that at the fifth cleavage stage one or two chromosomes stay in the middle of the spindle. When the daughter nuclei enter the resting period these two eliminated chromosomes, lying between the nuclei, swell up and stay for a time in the yolk as dark-stained clumps of chromatin. Eventually they



disappear. The supernumerary chromosomes may be eliminated in one cleavage or it may require two successive cleavages for their expulsion. Thus the elimination can be seen in the seventh, eighth or ninth cleavages. That chromatic material may be eliminated was already known, but this is the first time that elimination of whole chromosomes has been demonstrated. That any of these supposedly indispensable bearers of the genes may be thus spared is a matter of great theoretical interest. Dr. DuBois points out that the period during which the chromosomes are eliminated (fifth cleavage) is an important one, being the time at which the first two germ cells differentiate and locate in the posterior end of the egg. From then on the germ cells divide actively but no longer synchronously with the somatic cells.

Dr. C. W. Metz and Miss M. L. Schmuck have studied another instance of chromosome elimination in *Sciara* similar to or correlated with that described by Dr. DuBois. It has been found that through asymmetrical chromosome distribution each sperm regularly receives one or two extra chromosomes. To restore the chromosome balance it is therefore necessary to postulate a chromosome diminution at some stage in the life cycle. They find, however, in studying the maturation divisions of the egg that here there is no compensation for the excessive chromosome number in the sperms and are forced to conclude that the requisite elimination of chromosomes takes place during cleavage, in conjunction with the elimination occurring during differentiation of soma from germ-line. Thus germ cells as well as somatic cells exhibit the phenomenon of chromosome elimination. Dr. Metz and Miss Schmuck point out the probability that in the case of the germ cells it is concerned with sex determination.

In order to establish the fact that the oocyte divisions are regular in their chromosome behavior they resorted to the technique of studying the intact egg with chromosomes colored by the Feulgen reaction. They were thus able to follow the chromosomes during the maturation divisions and to trace the sperm during its progress in the egg until the union of the pronuclei. It may be added that only one sperm ordinarily enters the *Sciara* egg and it enters, presumably through the micropyle, during metaphase of the first oocyte division. It then approaches the egg nucleus during the procedure of the two maturation divisions.

#### GENETICS

During the past two years Dr. C. W. Metz and his coworkers have continued here in Baltimore the genetic studies on *Sciara* begun by them in the Department of Genetics at Cold Spring Harbor. They are temporarily provided with adequate quarters in the Department of Zoology of the Johns Hopkins University, also with some space in our laboratory. Dr. H. B. Smith has studied several new mutants obtained in part by use of X-rays. Three mutants possessing wing peculiarities that were of special interest were crossed by her in various ways and thus analyzed with respect to dominance, sex-linkage, and whether the male transmitted maternal and paternal characteristics equally. The characters were all found to be dominant, autosomal and in each case the males transmitted only the characters received from their mothers. They all showed the same selective segrega-

tion. Dr. Smith's experiments support the hypothesis that the sex of the parent influences the behavior of homologous chromosomes at the monocentric division.

In some species of *Sciara* the progeny are bisexual or digenic and in other species they are unisexual or monogenic. The genetic studies of Dr. Metz have been mainly concerned with the latter type and especially with the mechanism of sex determination. In the male the problem has been reduced to two alternatives; sex is determined either by the process of chromosome elimination, as described previously in this report under chromosomes; or in the ordinary manner by the union of a Y-bearing sperm and an X-bearing egg. Regarding the female, the data are not sufficient to enable one to speak as definitely as that. On the occurrence of unisexual progenies Dr. Metz seems inclined to accept the hypothesis that the eggs of female-producing females are selectively fertilized by X-bearing sperms, the Y-bearing sperms being inactivated or eliminated, whereas, in the male-producing females the process is just reversed.

During the past year Dr. Metz' Carnegie lecture on the development of the egg has been published in final form in a series with those of Dr. Hartman and my own. In it he gives a general presentation of how the chromosomes and genes play a primary rôle in the development of the individual. Many items in the evidence are taken from his own observations.

## THE NERVOUS SYSTEM

### NON-EXISTENCE OF SPECIAL SYMPATHETIC TROPHIC NERVES

Dr. S. S. Tower had previously shown that removal of the sympathetic chain in such animals as the cat, dog and goat does not result in trophic disturbances in the fibers of the skeletal muscles. The muscle-fibers of the fore-limb deprived of this sympathetic innervation reveal no morphological changes as compared with the normal side, in such characters as staining reaction, striation, number and size of nuclei, amount of connective tissue, and average diameter of muscle fiber. The possibility still existed, however, that the sympathetic nervous system might exert a trophic influence during the period of most active growth. Dr. Tower therefore undertook further experiments during the past year on recently born kittens, removing portions of the sympathetic system from one side. The animals then were allowed to grow for several months, when at varying periods they were killed and a careful comparison made of the corresponding structures of the two sides. In the living animal no difference on the two sides could be recognized in the hair, skin, muscles and bones. The only effect was a permanent loss of perspiratory and vasomotor function. On autopsy, gross and microscopic examination failed to show in the non-nervous tissues any alteration as a result of the sympathetic denervation. We must, therefore, conclude that the influence of the sympathetic nervous system is not necessary during the critical growing period from new-born to adult for non-nervous tissues to attain normal size and form.

Dr. Tower finds, however, that when the sympathetic ganglia are cut off from the central nervous system as they are in these experiments, they fail to attain their normal size and there is a reduction in number of cells and



those present are not entirely normal. She also finds that the preganglionic neurones, even in such young animals, do not replace postganglionic ones, nor do sympathetic neurones deviate from their allotted course to repair a defect. Of course, the sympathetic ganglia exercise a certain control over peripheral structures but it is something quite different from growth and maintenance of size and form.

#### INNERVATION OF SKELETAL MUSCLE

Applying suitable staining technique, Dr. S. S. Tower has continued her studies of the limb muscles, comparing the innervation of normal muscle-fibers with some deprived of sympathetic supply and with others in which each of the three components of innervation, dorsal root, ventral root and sympathetic, had been isolated by elimination of the other two. She finds in mammals, in contrast to the more complicated conditions in lower forms, a simple stereotyped form of innervation of skeletal muscle, common to most muscles and common to many species. It includes a medium-sized nerve-fiber of somatic motor origin, myelinated nearly to its point of entrance in the muscle-fiber envelope, and terminating with coarse ramifications among the nuclei of a granular sole plate, the typical hypoplemmal ending. With a simple uniform termination like this, a corresponding uniform response is obtained, namely maximal contraction. Different activities of muscles, tonic and phasic are obtained through the ability of the central nervous system to send down impulses varying in frequency and number. In no case did Dr. Tower find any accessory innervation, either sympathetic or of non-myelinated fibers of untraceable origin and there seems to be no need for any. Muscular and vascular innervations are separate things and at no point in their peripheral distribution do these two communicate. Vascular innervation is of course sympathetic. Dr. Tower points out that a simple uniform neuromotor unit has developed as a specialization in the limb muscles of higher mammals and with this all accessory innervations, common among the lower vertebrate classes, have been eliminated.

As another approach to an understanding of muscle innervation, Dr. Tower has studied degeneration of the muscle-spindles in the interosseous muscles of cats following four varieties of lesion: section of peripheral nerve, section of ventral root, section of dorsal root and excision of sympathetic ganglion. After establishing invariable atrophy and degeneration of the spindles, providing one gives them time enough, after sectioning the whole nerve and demonstrating the probability that the sympathetic fibers enter the spindles only in a vasomotor capacity, Dr. Tower undertook to determine what relative part is taken by the ventral root and dorsal root in the atrophy and degeneration. She discovered the interesting fact that atrophy tends to occur in the functional elements served by the disturbed nerves. After sectioning the ventral roots, it is the ends of the spindles that show the greatest atrophy and particularly the cross-striated substance and even in the middle of the spindle this substance is perceptibly reduced. On the other hand when the dorsal roots are sectioned it is the central aggregate of nuclei, composing the sensory epilemmal ending, which are shrunken or dispersed, whereas the contractile substance usurps the entire fiber. Dr. Tower points out the close structural and functional continuity of the

nervous and non-nervous elements in these end organs and suggests that a metabolic exchange may be necessary and that the lack of it results in atrophy and degeneration. This would appear to be a more adequate explanation than the heretofore prevalent concept of atrophy of disease. This would explain Dr. Tower's previous observation that sensory denervation of the cat's fore-limb, leading to its disuse, results in no appreciable atrophy. To produce degeneration a motor lesion is essential and an involvement of the syncytium uniting the nerve to the contractile elements of the muscle. It explains some of the observations made by Dr. F. Cuajunco, which I will now refer to.

During the past year the study of innervation of the neuromuscular spindles by Dr. F. Cuajunco has appeared in published form. The experiments were performed several years ago while Dr. Cuajunco was here as a visiting member of the anatomical staff. Using adult cats he cut the nerve roots at different levels and in some he removed portions of the sympathetic system, and after periods sufficient for degeneration to occur, the neuromuscular spindles in the large flexor muscles of the toes were prepared and studied microscopically. By differential nerve degeneration he was able to demonstrate that the spindles in these muscles may be either mono-, bi-, or tri-segmentally innervated and that consecutive segments of the spinal cord contribute to the supply of a given spindle, a feature of special embryological interest. He also studied the progress of degeneration of the spindle where the dorsal roots and ganglia were extirpated and found that the presence of somatic motor terminations in the intrafusal fibers prevents, or at least delays, the onset of degenerative changes. Inactivity of muscle, where that occurred in his experiments, alone did not appear to have any effect whatever on the spindles.

#### PHYSIOLOGY OF TACTILE SENSE

Dr. Marion Hines in an investigation of the cutaneous end organs of tactile sense has studied the effect of arresting their blood supply. By applying a series of various weights upon a given area of skin she found that when the weight is sufficient to exert a pressure equal to the blood pressure in the papillary and subpapillary vascular net, and so stops the circulation, there is then a definite raising of the threshold of tactile sense in the area concerned to the extent of finally totally interrupting it. This apparently explains the gradual loss of tactile sense that has been known to occur following continued pressure on the skin, and which had been supposed to be due to nerve-exhaustion or perhaps to adaptation to the stimulus. In the course of these experiments it was found that the nerve endings for pain which penetrate the epidermis, contrary to the tactile sense receptors of the corium, do not suffer any diminution in their excitability through pressure on the skin. If the loss of tactile sense were due to a mechanical paralysis, a similar pressure would likewise cause loss of pain. Mechanical paralysis is thus ruled out and the probability strengthened that the disturbance in circulation in the above experiments is the cause of loss of tactile sense. These experiments of Dr. Hines were conducted by her while a guest in the Physiological Institute of the University of Würz-

burg, where so much has been done in past years under Professor v. Frey on the functional elements of the skin.

#### REGENERATION IN SYMPATHETIC NERVES

Previous studies of regeneration in the sympathetic nervous system have been restricted to the cervical sympathetic cord by the fact that it was the only place where a satisfactory functional test could be applied, namely, the ocular response. Dr. S. S. Tower and Dr. C. P. Richter have recently succeeded in extending our knowledge of nerve injury and repair to other parts of the sympathetic system. By applying the technique developed by Dr. Richter for measuring skin resistance to the passage of weak galvanic currents, and the presence of action currents generated in the skin, they were able to determine the function or non-function of the sympathetic fibers to the skin. They cut the preganglionic sympathetic fibers before their entry into the stellate ganglion in a series of cats. The immediate effect of cutting these fibers was an increase of skin resistance of the foot pads to galvanic currents and an elimination of the action currents of the skin. Recovery occurred between the third and seventh week, averaging 28 days, and this may be assumed as proof of the repair of the cut fibers. Thus the preganglionic sympathetic neurons have a capacity for regeneration in a similar way and as quickly as other peripheral nerves.

There appears from the experiments of Dr. Tower and Dr. Richter to be some difference between the production of action currents in the skin and the determination of skin resistance. Section of the thoracic sympathetic trunk at various levels reveals that a level which may abolish the galvanic skin-reflex may not greatly influence the skin resistance. The most essential fibers appear to come from the fourth thoracic, others are contributed by the first, second and third. They found that the skin-action-currents and galvanic skin-reflex afford a vastly more sensitive index of the functional state of the sympathetic supply than observations of the activity of the sweat glands directly, although they both represent sweat gland activity.

#### CEREBROSPINAL FLUID PRESSURE

In a previous report an account was given of the work of Dr. Lewis H. Weed on the influence of postural changes on the pressure of the cerebrospinal fluid. He devised a tilting table by means of which the animal could be abruptly changed from horizontal to vertical positions, either head-down or tail-down, and the cerebrospinal fluid pressure recorded before and after and synchronously in the occipital and lumbar regions. He found in these experiments that postural changes are accompanied by dislocation of the cerebrospinal fluid and that the consequent changes in pressure are compensated for, mainly, by a slight yielding of the membranous wall of the spinal dural-cavity.

During the past two years these experiments have been carried further by Dr. Weed and Dr. L. B. Flexner. In the first place the experiment was altered by exposing in some animals the spinal dura to atmospheric pressure and in other animals the cranial dura. In the former the vertebral arches were removed throughout the thoracic and lumbar regions; in the latter



the skull cap was removed over a wide area. During the tilting experiments records were made of the pressure of the cerebrospinal fluid, of the venous pressure in the sagittal sinus, and of the carotid arterial pressure. These pressures go up when the animal is suddenly tilted from horizontal to head-down, and they go down when it is tilted to head-up. As compared with intact animals it was found that when the spinal dura is exposed, tilting head-down causes a greater increase in cerebrospinal pressure; whereas, when the cranial dura is exposed the decrease in pressure on tilting head-up is considerably less than when this is done in the intact animal. That is, the cranial vault is necessary for negative pressure. Tilting head-down with the opened skull and tilting head-up with the opened spine result in the same pressure alterations that occur in the intact animal because in these positions the intact bony inclosure is not essential for the protection of the central nervous system against pressure-alterations.

In their endeavor to reach a greater degree of accuracy in measuring pressure of the cerebrospinal fluid, Dr. Weed and Dr. Flexner have been joined by Dr. Janet H. Clark of the Physiological Laboratory of the School of Hygiene and Public Health. Heretofore they had used an open-end manometer with which there is some dislocation of fluid. In some of the tilting experiments where relatively large amounts of fluid are displaced it proved desirable to test their results by the use of a method with which pressure could be measured without dislocation of fluid. This need was met by the adoption of the "bubble manometer" in which a bubble of air is confined within a glass tube of small bore. The pressure from the animal displaces the bubble, and the reservoir pressure necessary to restore the bubble to its previous position gives the pressure within the animal without dislocation of fluid. They found that pressures which had been recorded with open-end manometers of 1 mm. bore did not vary greatly from those recorded by the bubble manometer. However, when larger open-end manometers were used, the pressure-alterations following tilting of the animal decreased in proportion to the amount of fluid dislocated in the manometer.

An artificial cerebrospinal system made of glass tubes and tambours covered with rubber membranes was set up by them. This was so devised that it could be tilted from the horizontal to the vertical and so duplicate the animal experiment. From this system a constant was obtained, expressing the ratio between fluid-dislocation and pressure-change, the magnitude of the fraction depending on the elasticity and capacity of the tambour membranes. In the animals it had been found that such a constant relationship exists. By means of it they were able to accurately determine the diminution of the volume of the brain and of the cerebrospinal fluid induced by the use of intravenous hypertonic solutions, bringing their physiology into the realm of mathematics.

An important summary of his researches and those of his coworkers upon the envelopes of the central nervous system has been incorporated by Dr. Lewis H. Weed in a chapter in Penfield's *Nervous System*. This will place his significant experiments before a wide audience of readers who will be able to apply them to clinical needs.

## THE PORPOISE BRAIN

The expedition to Cape Hatteras for obtaining whale material (porpoises) referred to in Year Book No. 27 yielded a number of items of value to the comparative anatomist and these have been mentioned from time to time in my reports. Another dividend is now to be accredited to that enterprise. During the past year Dr. O. R. Langworthy completed his study of the brain of this highly specialized marine mammal and it has been published in its final form. Among the features of particular interest is the mechanism of hearing and its highly developed nerve tracts and centers. In its ascendancy over the sense of vision it reverses the condition existing in other orders of mammals and here one sees the cochlear apparatus in its greatest perfection. In the genealogical forest, the porpoise can claim one of the topmost branches of this particular tree. Another feature of interest is the existence of the habenular apparatus and associated structures which have been regarded as wholly olfactory—although no vestige of the olfactory nerves or of the olfactory bulb could be found in these porpoises. The large cerebellar hemispheres connected by massive tracts with still larger cerebral hemispheres are interpreted by Dr. Langworthy as a coordinating mechanism adapted to the powerful and skillful swimming movements which characterize the animal. Dr. Langworthy sectioned the brains and made a microscopic study of the principal fiber tracts and nuclei, including a survey of the different regions of the cerebral cortex. The cerebral cortex is very highly infolded but at the same time primitive in its architecture, having relatively few cells and these being but poorly differentiated into layers. The explanation for the elaborate convolutions must rest on something else than intricacy of structure. Dr. Langworthy suggests that it may represent a means toward provision of an adequate blood supply.

## COMPARATIVE ANATOMICAL STUDIES

## EVOLUTION OF FACIAL MUSCLES

The extensive studies of facial musculature which he has uninterruptedly carried on since 1913 have been collected by Dr. E. Huber in the form of a book where in outline form he presents a summary of what is known of the morphology, neuro-physiology and psychology of this important group of muscles. Dr. Huber's studies have made him an authority on the comparative anatomy and physiology of the facial muscles and their evolution into the mimetic musculature of the primates. His observations on racial differences in facial musculature and racial differences in facial expression will be of interest to a wide group of readers. For the student of behavior there are included important aspects of the embryology of these muscles in negroes and whites, and their elaboration and modification during the prenatal and postnatal periods. He discusses the influence of language as a modifying influence in facial expression. Dr. Huber's mastery in the art of dissecting these difficult muscles and in their pictorial presentation have greatly contributed to the scientific value of the work.

## LIMB AND TRUNK MUSCULATURE

Dr. W. L. Straus jr. has studied a well-developed quadratus plantæ muscle occurring as a variant in both feet of a *Tarsius saltator*. This



muscle is a fundamental element of the mammalian foot musculature but seems never to have been seen before in either *Tarsius* or any of the Lemurs. Its absence is regarded as a specialization peculiar to the prosimians. That it may occur as a variant in the primitive primate is one of those facts with which the intricate network of evolution is being gradually woven.

An analysis of the muscle groups associated with the shoulder and pelvic girdles has been made by Mr. A. Brazier Howell. In comparing different animals he finds the pelvis originally possessed two groups, extensor and flexor, but due to the exigencies of the crawling posture the flexor group becomes divided into protractor and retractor groups supplied respectively by the obturator and ischiadic nerves. In therian mammals these three groups are represented by extensor, flexor and adductor groups. In the shoulder girdle consisting chiefly of dermal bones, the phylogenetic history is found by Mr. Howell to be more complex. The extensor component he finds made up of the scapula and its musculature, the coracoid flexors are reduced and the accessory coracoid element, analogous to the pubis, is not present in mammals. The adductor muscles are shifted to the interclavicle and sternum. Where muscles can be grouped according to their functional rôle the difficulties of the comparative anatomist become less insuperable.

In the anterior part of the chest wall Dr. E. Huber has followed the competition existing between the great pectoral muscle and the rectus abdominis muscle for the space over the lower sternal region, in which there are racial differences between the negro and white, depending on the width of the sternum. With a narrow sternum as seen in the negro the great pectoral muscles tend to interlace and cross the middle line. A similar competition is seen for possession of space on the fifth rib, and even the fourth, with corresponding recession of the lesser pectoral.

In these studies it becomes apparent that it is no longer sufficient, where phylogenetic considerations exist, to study modifications in muscles alone. With such changes one must also determine to what extent they are correlated with changes in the skeletal system. This is illustrated in a study made by Dr. Huber of the progressive reduction of the lower ribs and the modification therewith in the adjacent muscles which absorb the released internal intercostal muscles. There is clearly a tendency to a reduction of the thorax toward eleven pairs of ribs. Where there are more than this one can see the phenomenon of reduction in progress.

#### ANATOMY OF PRIMATES

As one of his studies on the anatomical characteristics of the primate body, Dr. A. H. Schultz has made a survey of the density of hair at different stages of growth and in different types of primates. As a measure of density he arbitrarily selected the total number of hairs on 1 sq. cm. of skin and a sample was taken from each of three regions of the body, namely; the scalp, the back, and the chest. Having the number for a given sample the total number of hairs for the region was calculated. In all, 71 different types of primates were examined and several races within the species *Homo sapiens*. In all forms the hair grows most densely on the head, somewhat less densely on the back and much less densely on the chest. The platyrrhines and gibbons are the most hairy and the anthropoid

apes and man are the least hairy, indicating a general evolutionary trend toward the reduction of hair in the largest primates. Thus human "hairlessness" is a matter of degree. Though man is the least hairy primate, there are smaller differences between him and some of the anthropoid apes than between the latter and the lower monkeys. The density of hair decreases with advancing age, although owing to a greater area the total number of hairs is much greater in late than in early stages of growth.

In another study Dr. Schultz has investigated the hereditary tendency to eliminate the upper lateral incisor teeth. In a previous study, as reported in Year Book No. 25, he had observed the variation in the jaws of man and monkeys and had pointed out the evolutionary significance of the trend toward reduction in the jaws and tooth rows. Recently he has acquired more material, including a pedigree in which the elimination of incisors is found only in females and is not transmitted by males. In general he finds that the reduction ranges from a decrease in size to complete disappearance. He finds that it is not a particular variation that is inherited but rather a tendency to vary in the direction of a reduction, and the inheritance seems to be effected in different manners in different families. Variation in the opposite direction, towards a large lateral incisor has never been observed although an increase in the number of incisors is occasionally seen.

From year to year Dr. Schultz has increased his primate material and data. This has enabled him to compare more completely man's anatomical characteristics and body proportions with those of other primates and so determine his place, or places, within this order. It is, of course, with the large anthropoids that the affinities are most striking. Such comparisons reveal trends in evolution and, in a recent review, Dr. Schultz presents many-sided evidence of the evolutionary trend from the more primitive conditions among monkeys to the advanced state of specialization attained in man and the three large apes. The characters in which he demonstrates definite trends include: body size, hair, tail, vertebræ, thorax, trunk, relative length of limbs, hand and foot. If extreme specialization in these features, that is, departure from the "primitive" conditions among monkeys, constitutes superiority, then man scores in only a few of them.

One of the taxonomic characteristics attributed to the Lemuroidea has been the complete-ring form of the tracheal cartilages distinguishing, as it was thought, this suborder from all other monkeys, the anthropoid apes and man. From the examination of the tracheæ of a representative series of primates, Dr. W. L. Straus jr. has found that completeness of the rings has less group constancy than was supposed. In several of the genera of the suborder they are incomplete. Completeness appears to be characteristic only of the genera *Lemur*, *Lichanotus* and *Propithecus*, and even in some of the lemurs the rings are incomplete. It is the case of another generalization proving fallible. Completeness or incompleteness of the rings is determined by some other reason than a means toward classification. The determination of suborders and genera must rest on the uncertain framework of unruly anatomical characteristics which are forever going out of bounds.

A comparative study of the brachial flexor group—the biceps brachii, coracobrachialis and brachialis muscles—as they occur in primates has been made by A. Brazier Howell and W. L. Straus jr. After studying material from representative forms of the order, they are unable to find in these muscles any distinct evolutionary trend. The variations are individual rather than generic. This is notable in the biceps of the gibbon which exhibits complicated connections with muscles outside the group, producing a mechanical arrangement perfectly adapted to the special arm requirements of this arboreal anthropoid. These investigators, however, find no evidence that it is in any sense a stage in the evolution of the biceps of man and the great apes. Nor is it the only way in which the problem of arm locomotion has been solved; they found in other skillful primate “brachiators” no trace of such an arrangement. Since the three muscles of this flexor group are all supplied by the musculocutaneous nerve, they must be regarded as coming from a common origin and which later differentiated into the existing elements. In the process of specialization there appears to have been much interchange of fibers between the coracobrachialis and the biceps. As to the two heads of the biceps, they regard them as both derived from an original coraco-antibrachial flexor and the shorter head representing the more lateral portion, which has migrated outward to acquire origin from the supraglenoid border. Among the higher primates there is a tendency for the two heads to fuse more completely and more proximally. The most constant of the brachial flexors is the brachialis muscle.

#### THE MONOTREME

In reviewing the comparative anatomical position of monotremes, Mr. Brazier Howell points out one anatomical character which the monotreme possesses that can not very well be regarded as a phylogenetic step toward the marsupialia and placentalia; namely, the type of limb support. In monotremes the heads of the femur and humerus are on the abductor side with the axis of the bone horizontal and underslung from the girdle joint. In the marsupial and placental forms, where the limb has assumed a vertical position, the heads of the femur and humerus are in the adductor side, which could scarcely have been derived from the monotreme condition and is additional evidence that the monotreme stock is distinct from that of other mammals.

#### RETIA MIRABILIA IN LIMBS OF MAMMALS

There are two types of blood vascular plexuses in the extremities of mammals. One of these is composed of simple plexiform anastomoses and perhaps represents a persistence of the primitive or embryological capillary form. The other type consists of highly organized vascular bundles which are specializations adapted to peculiar functional needs. It has been found by Dr. G. B. Wislocki and Dr. W. L. Straus jr. that such a viewpoint must be taken with regard to the special vascular bundles occurring in the extremities of sloths, lorises and the four-toed ant-eater. The typical, specially organized vascular bundles occur only in sluggish arboreal animals and it is seen in animals not closely related phylogenetically. These



investigators, therefore, conclude that this type of vascular architecture has developed in the sloths and lorises as adaptive convergences in conformance to their similar modes of life. Representatives of the simple anastomosing type of retia mirabilia are seen in the great ant-eater, armadillo, and the femoral arteries of Tarsius. Persistence of a primitive vascular pattern may prove a sufficient explanation in such cases, but it is something more than that in the organized types mentioned above.

## PHYSIOLOGY OF REPRODUCTION

### OVULATION AND THE MENSTRUAL CYCLE

By tabulating 111 ovulation days which he has been able to determine accurately in the Carnegie Colony, Dr. C. G. Hartman finds that the average ovulation occurs on day 14 in the rhesus monkey, counting the first day of menstruation as day 1. Almost all of the ovulations that do not fall on this day occur either during the three days before or during the three days after; that is, during the period from day 11 to day 17. Thus in an overwhelming manner ovulation is a mid-interval affair. The date of ovulation was determined in part by bimanual rectal palpation of the ovary, in part by inspection of the ovary at operation and in part by conceptions after controlled matings.

Clinical data obtained in women also point to the middle of the menstrual cycle as the time when ovulation takes place, but the clinician has heretofore maintained that it could occur at any time, even during the menstrual flow. A review has been made of this subject by Dr. Hartman and he points out the weakness of the evidence on which the gynecological opinion is based. He found that in the few unequivocal cases where the egg was actually recovered, ovulation occurred in the mid-interval and that the average for both man and monkey is about day 14.

The comparative physiology of menstruation may yield fundamental principles by which its essential nature can be better understood. It is for this reason that Dr. Hartman has been investigating uterine bleeding in a wide variety of animals in the form of a reconnoiter. He has found that uterine bleeding is of wide-spread occurrence. It begins with the cartilaginous fishes and is found in varying forms in the amphibia reptiles and throughout the mammals. Essentially throughout the whole vertebrate series, wherever, after passing the egg stage, the embryo depends for its development on the mother's body substance, one finds in the brood chamber red blood cells mingled with the secretions of that organ. These nutritional chambers, though varying so greatly in form, are with few exceptions derived from the same embryological source, the Müllerian ducts, and a peculiarity of the Müllerian derivatives is their ability to pass red blood cells through their lining membrane as a normal process. There are many types of bleeding. In man and macaque, which closely resemble each other in this respect, there normally occur: (a) menstruation with or without ovulation; (b) bleeding of implantation, the so-called placental sign; and (c) the intermenstrual or *mittelschmerz* bleeding. Certain phases of the phenomenon of menstruation, which have been studied by Dr. Hartman, I have referred to in previous reports. Some progress has been made in

the determination of the excitors and regulators of uterine bleeding in the primates, but for the lower vertebrates the work has not even begun.

#### EXPERIMENTAL PRODUCTION OF OVULATION AND SUPERFETATION

The studies of Dr. F. F. Snyder and Dr. G. B. Wislocki on the ovulation-causing substance in the urine of pregnant women, described in my last report, have been continued in further detail. It will be remembered that they found this substance only in women (possibly in apes) and only during pregnancy. Something regarding its nature is revealed by the fact that the same active substance can be recovered from the urine after injection into a rabbit; passing through the rabbit's kidneys does not appreciably alter it. They find that a smaller dose of it is effective when given intravenously than when given subcutaneously or intraperitoneally, but this would be expected. An important point that they were able to establish is the relatively short interval required for the total disappearance of the ovulation-producing substance from the urine when the uterus is removed. This would indicate that it is not of hypophyseal origin but more likely an excretion product arising from the chemical mechanism of human pregnancy. That it is also present in amniotic fluid may be similarly interpreted. The presence, however, of a substance in the anterior lobe, having the same power of causing ovulation in rabbits, is not to be explained in the same way. For this is not limited to the period of pregnancy nor is it limited to women. Though they both cause ovulation in rabbits, it does not follow that anterior lobe extract and the substance in urine of pregnancy are identical.

Another phase of the problem taken up by these investigators was the determination of the age at which ovulation can be induced in rabbits. They found that the substances from urine of pregnant women and anterior lobe extract in standard dosage have no effect in young rabbits before the end of the third month. At about that time the ovaries begin to be markedly affected; after such injections they become oedematous and show hemorrhages or hemorrhagic follicles. This suggests their immaturity as the explanation for hemorrhagic follicles frequently met with in the absence of experiment. After the seventh month the normal response to injection is ovulation, although there are refractory periods following previous ovulations and in pregnancy and pseudo-pregnancy. They find that in the pregnant rabbit after the first four days new ovulation can be induced by using sufficiently large doses of either concentrated urine of pregnancy or anterior lobe extract.

That ovulation can be induced during pregnancy made it possible for Dr. Wislocki and Dr. Snyder to perform an experiment of much theoretical importance. They were able to demonstrate the possibility of superfetation in the rabbit. Many cases of superfetation have been reported in the past but they have been all in animals in which plural birth is normal and in most of them it was possible to show that the apparent superfetation was no more than intrauterine death of some of the individuals at earlier stages of pregnancy. The evidence was such that the belief gained ground that superfetation could not take place. The experiments of Dr. Wislocki and Dr. Snyder now make possible a new approach to the problems of



implantation. They show conclusively that it is not the migrating ova that exert the strong inhibition to ovulation that occurs during pregnancy. We must now assume that the influence of the ovum does not begin until about the time of its implantation; that is, until its trophoblastic shell is sufficiently differentiated to become functional. They have demonstrated that not only can a second set of ova be made to come down during the presence of a previous, fertilized set, but that also by artificial fertilization the second set may be started on their way in development. At a time when the primary set of ova had become definite blastocysts, a secondary litter of normal-appearing eggs in one- and two-cell stages were brilliantly demonstrated in the tubes following experimentally induced ovulation and artificial fertilization in a rabbit normally mated four days previously. It is of great interest that the sperm, introduced in the vagina by means of a glass pipette, reached the second set of ova without being deleteriously affected either by the blastocysts or by the changes in the genital tract following the initial mating. This circumstance must be kept in mind when consideration is given to the observations of Dr. Hartman and Dr. Ball on the transport of sperm in the rat.

#### Eggs

Through cooperation with the Bureau of Dairy Industry, United States Department of Agriculture, a study has been made of the ovum of the cow and with it a complete clinical history was assembled of the animals from which the ova were obtained. Mention was made of this study in my last report. Since then it has been published in its final form. As far as I know this is the first time that tubal ova of the dairy cow have ever been seen. There are more difficulties involved here than in many other mammals and of course it would not be a suitable form for study where many eggs are required. Enough was gained from this study, however, to determine the main features of fertilized and unfertilized tubal eggs in this animal. The features noted were the measurements of the egg and inclosing zona, the character of the cytoplasm and nuclei, and the relations of the blastomeres at the two-cell stage. A satisfactory motion-picture film was obtained, the individual frames of which yielded this desired information. It was found that the cow's egg is 135 to 140 microns in diameter, measured in the living state and taking the inner diameter of the zona as the true size of the vitellus as it leaves the ovary. According to our records this is about the same size as that of dog and man but is definitely larger than that of the rat and mouse.

During a visit in the summer of 1931 at the Tortugas Laboratory, Dr. C. G. Hartman found that the number of eggs in the ovary of a fish can be accurately determined by the application of a volumetric method, previously used by other investigators for determining such things as the number of glomeruli in the kidney. It consists in immersing a piece of the ovary in hydrochloric acid, resulting in disintegration of the ovarian framework and the releasing of the eggs. The material is shaken in a flask to become a smooth suspension and the eggs are then counted in measured samples. Since it was known by weight of the two intact ovaries what proportion the disintegrated piece represented, the total egg population can readily be

calculated. Dr. Hartman found by this method that in a barracuda, caught in July, measuringly slightly over one meter long, there were in the two ovaries 4,410,000 eggs, an ample provision.

A study of the muskrat egg, supplementing our investigations of other mammalian eggs, has been completed by Dr. R. R. Squier and is in preparation for publication. A review of his work is reserved for my next report. It happens that propagation of the muskrat is of considerable economic importance and for this reason a study of the reproduction requirements and commercial possibilities of the muskrat has been made and recently published by Dr. R. K. Enders. During the past two years, Dr. Enders has been associated with this laboratory as Fellow of the National Research Council. His studies have been principally concerned with the embryology and physiology of reproduction in the murine or pouchless opossum found in the Panama region.

#### TRANSPORT OF SPERMATOZOA

It has been largely believed heretofore that transport of spermatozoa through the uterine tract is accomplished by a propelling action of their vibratile tails. Whatever may be the purpose of the characteristic lashing of the spermatozoan tails, the theory that it is for transport has been rendered obsolete, at least for the rat, by the convincing experiments of Dr. C. G. Hartman and Dr. J. Ball. They have shown that the transport of sperm is much too quick either for ciliary action of the endometrial epithelium or for movements on the part of the sperm itself. From the moment of ejaculation it requires less than two minutes for the distribution of the sperm throughout the whole uterus and to the distal ends of the cornua. The only agency that would appear to be equal to this is the activity of the uterine wall itself, the peristaltic contractions of whose smooth muscle are plainly visible. This rapid transport of the sperm in the rat is facilitated by the fact that during œstrus the uterine horns are tensely distended with fluid which thus converts them into efficient mixing chambers.

After determining reliable criteria for the "effective" copulation, it was only necessary to survey the uterine content of a series of rats killed at different intervals after the entrance of the sperm into the uterus. This was facilitated by placing a clamp near the distal end of the cornua. This could be done quickly and it insured that any sperm found beyond that point had arrived before the placing of the clamp. Spermatozoa were found distal to a clamp which was placed near the tubal end of the uterine horn 100 seconds after the moment of ejaculation. In specimens taken at two or more minutes, spermatozoa were invariably found at the extreme tip in large numbers. In animals whose uterine cavities are not similarly distended with fluid, this rapid ascent would not be attained so easily and the tails might then serve as an essential transport agency.

#### PHYSIOLOGY OF BIRTH IN MONKEYS

It has never been possible to study satisfactorily the contraction waves of the human uterus during the mechanism of birth, the reason being that the welfare of the patient does not permit complete exposure of the uterus

for observation. In the monkey, however, the way is open, for here the animal can be justifiably sacrificed. Thus for the first time it has been possible to determine the contractional behavior of the parturient uterus in a primate. The study was made by Dr. C. G. Hartman and Dr. A. K. Koff with the cooperation of Dr. A. C. Ivy of Northwestern University. Dr. Ivy, who visited our laboratory for this purpose, had previously studied uterine contraction waves in the dog and rabbit during parturition. He thus was already skilled in a technique suitable for the undertaking. His method comprised complete exposure of the intact uterus for direct visual examination and for motion picture records. These records were supplemented by observations on response to mechanical, electrical and chemical stimulation. Finally the uterus was emptied and its postpartum contractions were recorded by inserting tandem kymograph balloons (fundus and cervix).

They were able to establish that the contraction waves usually start bilaterally near the insertion of the tubes, the points from which they start not participating in the contractions. The widening concentric waves meet at the middle line and pass caudally through the lower segment of the uterus to the cervix, the whole process consuming from three to eight or more seconds. The placental sites are less involved than the remainder of the uterus, although after delivery it is these regions that exhibit the most marked contraction. These investigators find that physiologically the uterus is composed of an upper and lower segment distinctly separated by a contraction ring. This is important to the comparative anatomist as the lower segment appears to be the homologue of the corpus of bicornuate uteruses, whereas the upper segment represents the fused horns with the contraction ring as the cornual sphincters. Regarding the musculature of the cervix, they find that it is chiefly concentrated into a strong sphincter at the internal os. This can be felt by the finger as a definite ridge in the lumen and can be seen externally.

The above study of the muscle contractions of the parturient uterus was supplemented by an anatomical and hysteroscopic survey of the birth canal by Dr. F. v. Mikulicz-Radecki of the Woman's Clinic, University of Berlin. By use of a specially devised mirror this investigator was able to bring into clear view the entire interior of the distended and illuminated uterus. Visiting our laboratory for this purpose he studied the uterus of a monkey that had given birth 18 hours previously and he repeated the examination 24 hours later. He found that, as in the human, there is a lower segment of the uterus, of a different functional significance, which is more easily distended than the remainder of the uterus and which exhibits but slight changes in the mucous membrane and is devoid of thrombosed vessels. In contrast, the upper segment is more resistant to distention with salt solution and its lining membrane is thrown up in oedematous ridges with thick tags which can be seen moving in the current of the distending fluid. Here and there large thrombosed vessels can be recognized, particularly on the anterior wall. The rapid progress that is made in healing was proven by the subsidence of these phenomena occurring in the 24-hour interval between the two examinations. The appearance of the cervical lumen differs widely from that of the uterus and vagina. It shows a great



quantity of whitish strands, the pressed-out septa of the cervical glands, actively waving in the irrigation fluid.

The hysteroscopic observations were checked by Dr. v. Mikulicz-Radecki by examination of celloidin sections of the parturient uterus from another of our animals, of which he made a complete anatomical study. A point of especial importance is the mechanism he found to exist for arrest of bleeding after the detachment of the placenta—a mechanism that is highly efficient in the monkey. This appears to be effected jointly by the intrinsic contraction of the large vessels and the throttling action of the uterine muscle strands that interlace among them. Thus in sections of the uterus the blood-vessels of the muscle layer are empty and markedly contracted, whereas the vessels of the mucous membrane are filled with blood. The escape of this latter blood is largely prevented by thrombosis. Because of these provisions, the examination of the animals can be performed with almost no bleeding, and associated with this there appears to be a marked protection against puerperal infection. So much so that it is not necessary to sterilize the instruments or the examiner's hands.

Another important factor of the birth mechanism is the alteration that occurs at that time in the bony pelvis. This has been studied in the macaque by Dr. W. L. Straus jr., who finds that during parturition the bony canal in monkeys undergoes marked spreading. The relaxation is greatest in the sacro-iliac joints and also occurs in the pubo-ischiadic symphysis. Due to these changes the ischial tuberosities can be easily pressed apart, denoting a relaxation of the pelvis that can be demonstrated for some days before and persisting until some days after parturition. Dr. Straus has not studied these tissues microscopically to determine the histological basis for these alterations nor has it yet been possible to do more than speculate on the hormonal or constitutional agents that effect the change. In watching the birth of the head, no evidence could be seen of its rotation within the pelvis such as occurs in man. Dr. Straus attributes this to the shape of the bony canal and to the absence of a true pelvic diaphragm. The muscles, which comprise the diaphragm in man, can be recognized as the flexors and abductors of the tail in monkey and in the latter they have but slight connections with the pelvic viscera. This enables them to play a more obvious part in this animal's activities but perhaps not a more important one than that assigned them in the "higher" primates.

#### ABNORMAL BIRTH IN MONKEYS

In previous reports, reference has been made to observations of Dr. C. G. Hartman and Dr. O. L. Tinklepaugh on birth in monkeys, both with respect to the detailed behavior of the mother and also of the new-born baby. In the meantime further pregnancies have been studied and the mechanism of birth observed in additional cases and in further detail. We were fortunate in having, as an additional observer in some of these cases, Dr. E. Philipp of the Universitäts-Frauenklinik, Berlin, giving us the benefit of his wide experience. Among the monkeys of the Carnegie Colony over 40 births have occurred. Of these, some have twice given birth to young. Two of them occurred in two successive years. Thus there have accumulated sufficient data to give an indication of the range of variability in the details

of this complicated mechanism and to mark the normal from the abnormal and pathological.

Among the abnormal cases one of particular interest was a face presentation that was studied in detail by Dr. Philipp. The delivery was spontaneously effected in the manner typical for man. Another case involved a 14-year old animal in which there was a rigid, resistant cervix. The labor in this case was prolonged to 32 hours, the fetus being then born dead. Usually one hour of active pains is sufficient to expel the young, and it is not unusual to have them protracted to two hours. But the case mentioned is far beyond the range of normal variability. In other instances there were still-born young and miscarriages at different stages of pregnancy, resembling corresponding phenomena in human pregnancy. It is evident that in this animal, the possibility exists for an experiment-controlled study of these problems, which are of such great importance in the human. The clinician does not yet realize the extent of this opportunity.

#### RELATIVE STERILITY OF THE ADOLESCENT

There has been a lack of agreement among students regarding the phenomena of puberty and maturity, the prevailing usage being to refer to them as one and the same thing. Observations have been made by Dr. C. G. Hartman which serve to remove some of the confusion that has existed. In his monkey colony he has had an excellent opportunity for studying the whole course of adolescence. He has come to the conclusion that puberty should be reserved for the beginning of adolescence and maturity used to denote its completion. Under puberty should be included the first manifestations of gonadal activity and the onset of sex color, menstruation, cyclic variations in spontaneous activity and cyclic changes in the vagina.

He studied fifteen female rhesus monkeys, in which every menstrual cycle from the very first was observed, and in which the body growth, changes in secondary sex characters, and changes in the ovaries and genital tract were all recorded. They were regularly mated with males soon after puberty but it was found that an interval of about one year elapsed between the first menses and the first conception. Dr. Hartman thus defines maturity as the time when the first ovulation takes place and when the uterus acquires the changes necessary to carry the offspring to term, and he points out that it marks the end of adolescence. In the fifteen macaque females studied, the average weight at the first menses was 3350 grams, but in nearly all cases it was not until they reached 5000 grams that conception ensued, and many menstrual cycles had already run their course.

Similar successive stages of adolescence apparently occur in the rat and mouse and it evidently is true for the human race. In other words, the onset of menstruation in a girl does not mean the capacity for conception. On the average the latter, or full maturity, is attained only after three or four years.

#### HORMONES

The facts thus far known regarding the part that the glands of internal secretion play in the growth and maturation of the egg, in its fertilization, its transport to the uterus and in its subsequent nurture and final birth



have been assembled by Dr. C. G. Hartman in the form of one of the Institution's lectures in Washington. In this lecture one finds an emphasis on the extent to which the physiology of reproduction is dominated by the interplay of hormone reactions, particularly between the anterior lobe of the hypophysis and the ovary. Dr. Hartman was able to illustrate this largely from his own material observations.

#### HISTOLOGY OF THE STIMULATED OVARY

Hormones have been referred to in previous reports and as time goes on are likely to receive increasing attention. During the past year Dr. Hartman with Dr. R. R. Squier completed an histological study of the material from an experiment demonstrating the follicle-stimulating effect of transplanting the anterior lobe of the pig hypophysis into rhesus monkeys. It had been found that if the substance of the gland is minced with the forceps and scattered in successive implantations along incisions made in the monkey, there results a marked stimulation in the growth of the ovarian follicles. In nine days the ovaries were found to increase in size ten- to fifteen-fold. When such ovaries are sectioned it is found that their increase in size is due to the growth of a large number of atretic follicles. The degenerative process involved the granulosa membrane, the cumulus, and although ova are present they exhibit no evidence of maturation. There was no indication of luteinization nor could any be expected in such follicles.

In addition to the presence of large abnormal follicles, these stimulated ovaries possess another striking feature in their excessive vascularity. Throughout the whole organ, and the uterus also participates in this, the blood-vessels are very prominent. The vessels form large dilated plexuses gorged with blood. Blood is found in the lumen of the uterus, although there is no general extravasation and it is not quite clear how the blood makes its egress. It is obvious that unharnessed action of the anterior lobe such as is seen in these cases is not yet adaptable to clinical usage.

#### SPONTANEOUS UTERINE CONTRACTIONS

Renewal of our studies upon the nature of rhythmic contractions of uterine muscle has been made possible through a visit to this laboratory of Dr. S. R. M. Reynolds, Fellow in Medicine of the National Research Council. Dr. Reynolds came equipped with a technique for recording in rabbits the contractions of the entire uterus, still in place, a technique which he had perfected in collaboration with Dr. M. H. Friedman of the University of Pennsylvania. Our previous experiments had been made with excised muscle strips suspended in suitable solutions. With his "uterine fistula" technique Dr. Reynolds was able to test uterine contractions under conditions essentially normal and in the live animal while still subject to experimentation.

In his previous work it had been shown that powerful uterine contractions in the rabbit precedes coitus and that within a few hours after that event, and preceding the release of the egg, an abrupt cessation of motility occurs and the uterus remains quiet throughout pregnancy or until the end of pseudo-pregnancy. Also castration is invariably followed by quiescence of the uterus in one or two days' time. Activity may, however, be restored

by giving the hormone of œstrus, œstrin, and this is the only agent thus far known that will do this. This is a specific replacement therapy and it demonstrates that œstrin is the causative agent for the initiation and maintenance of the powerful uterine contractions seen at œstrus. There remains to be demonstrated what it is that checks the stimulating action of œstrin under certain physiological conditions, such as pregnancy. Dr. Reynolds has now started some experiments with a view to determining the extent to which the hypophysis may be involved in this repression.

It may be added here that the possibility of successful removal of the hypophysis in the monkey is due to Dr. W. M. Firor of the Department of Surgery. In collaboration with Dr. Hartman he devised a suitable technique consisting, essentially, of asperating pieces of the gland through a glass pipette. After its performance in 25 cases, all but 6 of which were successful, the detailed procedure has been published. Through the use of such experimental animals we are now endeavoring to determine more facts regarding the hormonal activities of this organ.

With the improved technique for recording uterine motility available, it became of interest to determine to what extent, if at all, this phenomenon is affected by administering the ovary-stimulating substance contained in urine of pregnant women. Dr. Reynolds approached the problem in three ways: (1) he gave the urine-substance in small doses, enough to stimulate the ovaries but not enough to cause ovulation; (2) large doses sufficient to produce ovulation; and (3) administration of the urine-substance in rabbits whose ovaries had been removed and whose influence could consequently be ruled out. In group 1, with small doses, there was a variable decrease in uterine motility but the decrease was transitory. In group 2 with large doses of the urine-substance, enough to cause ovulation and luteinization, there resulted marked and continued uterine quiescence. This might mean that the urine-substance had caused ovulation and the ovulation in turn had arrested the uterine motility. Thus his group 3 was of interest because here there were no ovaries. It was, however, complicated by the fact that castration itself arrests uterine motility, and one can not arrest motility that is already stopped. Therefore for the test it was necessary to set up motility in castrated animals by resort to œstrin or theelin, which are ovarian derivatives, and, therefore, an ovarian influence was still present. Under these conditions a decrease in the "stimulated" uterine motility was clearly shown—which proves at least that the reaction may occur in the absence of the ovary, though it is probable that when the ovary is present it contributes to the effect. An interesting corollary of these results is that when injection of the urine-substance is followed by decrease of uterine motility one may be sure that ovulation has taken place, and when marked motility persists 24 to 48 hours or longer after urine-substance injection, then it is certain that ovulation has not taken place.



# DEPARTMENT OF GENETICS<sup>1</sup>

C. B. DAVENPORT, DIRECTOR

## GENERAL STATEMENT

This Department has always pursued genetics as a pure science. No considerations other than those of the working out of natural law, through the solution of fundamental problems, may properly play a part in our researches. Due to the fact that any organism is extremely complex, it was early seen that progress would best be made by each investigator working through the years with a particular organism, so that he might become thoroughly familiar with its genetical qualities. An advantage was anticipated in having a number of investigators, or groups of investigators, each working on a different organism, plant or animal. Thus would it be possible to separate the general and fundamental organic phenomena from the specific and trivial. Thus, of late years, our studies have been made of *Datura*; variegated plants, especially *Delphinium*; among insects, *Drosophila* and *Sciara*; several species of *Daphnidæ*; among birds, the *Columbidæ*; among the lower mammals, mice. About 23 years ago the human species was included in our program.

Now, *Homo* is not a good animal for genetical work. The time between generations is much too long; litters are too small, with usually only one at a birth, and the total progeny of a pair absurdly small; matings are uncontrolled and, under the mores, uncontrollable. The long time between generations would not be so bad if adequate records were kept of morphological and physiological characteristics, including performance. But such records are sparse indeed; and there are obstacles to obtaining the records.

However, despite all these difficulties, man offers certain advantages. In no other species has the technique for individual analysis been so fully worked out, thanks to the anatomist, physiologist, pædologist, psychologist, psychiatrist, endocrinologist, roentgenologist, and investigators in all the different medical and surgical specialties. Certainly in the field of inheritance of mental traits the human material is unsurpassed.

Moreover, even if *Homo* is poorly adapted to the discovery of new genetical principles, the testing out of such principles as have been worked out in other organisms is conceived to be of great importance. Too long have the problems of human well-being and progress been almost exclusively in the hands of philosophers and environmentalists, including sociologists and medical men. These have, at times, resented the entrance of the geneticist into the territory on which they have for so long a time squatted; but that must not deter him from performing his duty to mankind in declaring a part of this field to be his own.

The Department of Genetics of the Institution affords an unusually advantageous setting for research in human genetics. It is in constant

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touch with the revelations of animal and plant breeding, of cytological research, of bio-chemical analysis. It is thus in a position to make use of interpretations based on such researches. Thus, may be cited the revelations of the work on mouse breeding. This has thrown light on intra-uterine deaths, by which the race is early purified of its most inferior zygotic combinations. The experiments on mice and on daphnids have made still clearer the consequences of inbreeding; and its potentialities for race regeneration. Mice and pigeons have thrown much light on the origin and meaning of certain developmental defects that are found also in man. Especially illuminating have been the researches on dwarfism and leukemia in mice. The work with pigeons is of aid in the interpreting of those endocrine functions that play so important a rôle in human physiology and disease. The work on plant variegation throws light on all development, including that of man. The observation of irregularities in the chromosomal complex of *Datura* may be expected to aid in the interpretation of some abnormalities in human development. Principles discovered in any part of the world of organisms are of wide-spread application.

In another way the Department is advantageously situated for fundamental human studies, and this is because of its relation to other departments of the Institution engaged in related work. It has been happy to assist in the Maya problem by considering the constitution of the Maya Indians of today in their home in Yucatan and the development of their traits. It anticipates with pleasure the opportunity further to cooperate with the Department of Historical Research in its proposed study of eminent families and the rôle they have played in history. It has collaborated intimately with the Department of Nutrition in the study of pigeon metabolism and the human racial differences in basal metabolism and in changes in the rate of basal metabolism at different phases of child development. More and more the human studies in this Department must tie up with those of the Department of Embryology. The interaction of a number of investigators studying the same material, man, from different points of view and with differing techniques is being unusually fruitful of results.

Already the studies on genetics are exerting an influence on the fundamental philosophy of the sociologist and the medical investigator. Some educators are seeing more clearly the fact of innate differences in mental capacity in children. The head of the pathological department of Columbia University, who has been cooperating with us in the mouse leukemia project, has declared, in effect that henceforth pathologists and geneticists must work together. Otologists have subsidized a research into the genetic factors present in otosclerosis. An ophthalmologist has left a fund to be spent largely for research into the heredity of eye defect. A revolution is occurring in medicine; constitution is being recognized widely, as it has always been sporadically, as not less important than *conditions* (including parasites) in the history of any disease. A wide-spread change in point of view is imminent in consequence of which philosophy and sociology more and more will be guided by biological and, especially, genetical discoveries.



## DETAILED REPORTS ON CURRENT INVESTIGATIONS

## MUTATIONS

## DROSOPHILA

It is said that one of the topics with which the ancient Greek philosophers sharpened their wits was: Which came first, the egg or the hen? Some years ago, Bateson concluded that modern genetics had answered that question definitively in that it had demonstrated that it was in the process of maturation of the egg that the new mutation, which was a necessary first step in the formation of a new species, first appeared.

Today we are not so sure about this. Evidence is accumulating that mutations may, and do, occur at various ontogenetic stages in the development of the individual, and in so far as they affect primordial germ cells they may affect the race. One of the clearest cases of this is found in *Drosophila virilis*, as worked out by Demerec. There is a gene that is responsible for a so-called miniature (or miniature-3) wing. Three types of this gene are known, as set forth in earlier reports. These are:  $\alpha$ , which mutates both in germ-cells and somatic cells;  $\beta$ , which does not mutate back to the wild type at all; and  $\gamma$ , which mutates only in somatic cells.

## INSTABILITY OF THE GAMMA GENE

This miniature gamma gene is a sex-linked one; *i.e.* all female flies carry two sets of the gene and all male flies carry one set only. If the gamma gene had the same rate of instability in both sexes, expectation would be that in homozygous females there would be twice as many mosaic (mutated) flies as in the males. But in some thousands of each sex Demerec found that the proportion was the same. On the other hand, the mosaics produced by females heterozygous for miniature gamma and a stable miniature were only half as numerous as those produced by males. These experiments indicate, concludes Demerec, that the rate of instability of the gamma gene is about twice as high in males as in females. Any possible differential influence of the female cytoplasm upon the gene coming from the male was ruled out by the nature of the experiment. Since from females that were homozygous for the gamma gene (with 2 sex-chromosomes affected) about twice as many mosaic flies were found as among females that were heterozygous for the gene (with only 1 sex-chromosome affected), it follows that the rate of instability of the gene is the same in the homozygous and the heterozygous conditions.

In an attempt to find the factors that control the frequency of the somatic mutation of the gamma gene, varying temperature was employed, following the successful attempts of Muller to influence mutation, in general, by this means. From a single batch of fraternal eggs, gamma flies were hatched at 20°, 25°, and 30° C., respectively. From over 10,000 flies, mosaic wings were produced in the following percentages: at 20°,  $11.07 \pm 0.41$ ; at 25°,  $10.98 \pm 0.47$ ; at 30°,  $9.06 \pm 0.35$ . The flies reared at 30° were smaller and had shorter wings. Since the smaller number of mosaics observed among these flies is probably due to the technical difficulty of detecting minute mosaic regions on small wings, it is evident, Demerec concludes,

that the range of temperature used in this experiment has not affected the stability of the gamma gene.

While external factors are slow to increase the instability of the gamma gene, there are internal factors that do so regularly. Last year were described three modifying genes which increase the somatic instability of the gamma gene. These were called *S-1*, *s-2*, and *S-3*. This year still another has been found; it is called *S-4*. This gene stimulates somatic instability of the alpha and gamma genes and also makes these genes unstable at an earlier stage in ontogeny.

Demerec finds that gamma and alpha flies carrying the *S-4* gene have mosaic wings; *i.e.* wings that have mutated back to the wild type in spots. Among these mosaics a few are found with one wing of the wild type and the other wing either miniature or mosaic. Until *S-4* became known, mosaics of such type had never been observed. These mosaics indicate that the change from miniature to wild type occurs early in ontogeny; in other words, the miniature-3 gene under the influence of *S-4* becomes unstable at stages of ontogenetic development at which previously it had always been found to be stable. As mentioned in last year's report both miniature-3-alpha and miniature-3-gamma are stable during the first eight nuclear divisions following fertilization (otherwise we would have flies at least one of whose wings would be normal, or wild-type, and some of whose germ-cells would be wild-type). After these eight divisions the germ cells separate from the somatic cells. Thereafter the alpha gene becomes unstable both in somatic and germinal tissue and the gamma gene in somatic tissue only. Experiments indicate that *S-4* does not influence the stability of the gene during these first eight nuclear divisions but it begins to act only after the separation of the germinal tissue is accomplished. Probably *S-4* originated in our cultures. It was not until the line in which it arose had been under observation for 38 generations that the mosaics characteristic of *S-4* were first noticed. Demerec reports further:

"*S-4* is a simple Mendelian dominant. Except for the stimulating action on the miniature-3 gene, no other effect has been noticed to be due to *S-4*. Since the *S-4* acts as a strong stimulating agent upon the instability of miniature-3, practically all flies carrying that gene have mosaic wings, usually showing several wild-type spots. It is, therefore, a simple matter to distinguish flies carrying *S-4* from those having its wild-type allelomorph. In families segregating for *S-4*, ratios agreeing closely with expectancy are obtained."

The instability modifiers are genes having a variety of locations in the chromosomes. Thus it has been found that *S-1* is located in the right end of the second chromosome, 30.6 units toward the right of rounded; *s-2* was found to be located in the fifth chromosome. *S-4* is not located in the second, third, fourth nor sixth chromosome; it is, therefore, probably in the fifth. This hypothesis is being tested.

#### CROSSING-OVER IN THE X-CHROMOSOMES OF *DROSOPHILA VIRILIS*

The genes are distributed along the chromosomes at definite, but unequal, intervals. A crossing-over takes place between the genes of homologous chromosomes and such crossing-over is more frequent the farther apart

the genes. Based on the totals of the crossing-over between pairs of genes, one computes the total "genetic length" of the chromosome. The genetic length of the X-chromosome of *D. virilis* indicates that crossing-over occurs in this species with higher frequency than in *D. melanogaster*; this problem was accordingly investigated. The results are shown in the chromosome map of figure 1. This lists the factors used in the experiment and gives their location. The 4 factors placed above the line in the figure came from one parent; the 4 below from the other parent.

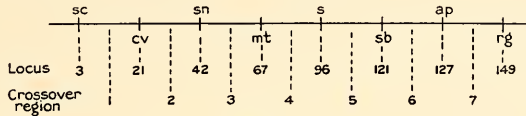


FIG. 1

As expected, crossing-over was found to occur with unusual frequency. This appears from a comparison of the percentage frequency of single cross-overs and multiple cross-overs of various degrees, as given below. The data for *melanogaster*, introduced for comparison, are as summarized by Anderson and Rhoades.

Total percentage occurrence of different multiples of cross-overs

	Number of flies	Multiples of cross-overs					
		0	1	2	3	4	5
<i>virilis</i> . . . . .	1890	16.98	37.67	28.04	12.65	4.29	0.37
<i>melanogaster</i> . . . . .	26908	45.95	46.24	7.64	0.17	0.0074	

Thus, while very few cross-overs involving 4 regions were observed in *melanogaster* and none involving 5 regions was found among 26,908 flies, such cross-overs are frequent in *virilis*. Even cross-overs in 6 regions may be expected when the numbers become larger.

"Coincidence between observed and expected crossing-over in any two regions was found to be high. Coincidence was generally higher for the adjacent regions located farther apart. Coincidence for regions 4 and 1 is 0.64; 4 and 2 is 0.95; 4 and 3 is 1.05; 4 and 5 is 1.21; 4 and 6 is 0.80; and 4 and 7 is 0.73. Similarly coincidence for regions 5 and 1 is 0.37; 5 and 2 is 0.40; 5 and 3 is 0.46; 5 and 4 is 1.21; 5 and 6 is 1.48; and 5 and 7 is 0.52."

Finally, the percentage of cross-overs in the different regions that are single cross-overs is variable. Thus, this percentage is in region 1, 19.1 per cent; in region 2, 25 per cent; in region 3, 30 per cent; in region 4, 23 per cent; in region 5, 29 per cent; in region 6, 6.5 per cent, and in region 7, 27.8 per cent. Region 6 being one with low percentage of single cross-overs must have a large proportion of multiple cross-overs.

#### MINIATURE-3-ALPHA, BETA AND GAMMA ARE MULTIPLE ALLELOMORPHS

The fact of the existence of three different genes occupying (in different individuals) the same locus in the chromosome has been often noted before

and constitutes the phenomenon of multiple allelomorphism. This phenomenon has not received the attention it deserves, since it is possible through it to obtain a deeper insight into the nature of the gene and indeed of the organic molecule, in general. Correns in 1919 has, indeed, considered it as evidence that, with the great central molecule of the gene, atom groups were associated; atom groups that could be withdrawn from, or added to, the central molecule, thus altering its qualities without disturbing its location. Eyster and Demerec have thought of the gene as composed of more elementary units (genels, of Bridges) and Thompson has recently urged his side-chain theory of the structure of the gene, according to which atoms or ions may be added to, or subtracted from, the main body of the nucleus without altering the locus of the gene, but permitting a graduated change in its qualities, according to the amount of change in the elements of the side chain. The systematic study of multiple allelomorphism, as a means of analyzing the organic molecule, is much to be desired.

#### CHANGE IN DOMINANCE IN THE RUFFLED GENE

Mr. G. A. Lebedeff discovered that the fifth chromosome recessive gene, ruffled, becomes dominant when together with the second chromosome dominant gene, rounded. In addition to a change in dominance these two genes interact in such a way that a new character "roofed wings" appears. He found also that a similar relationship exists between ruffled and the sixth chromosome dominant gene, clipped. Rounded and clipped are similar in effect, they both affect the shape of the wings. Tests made with other genes affecting wings revealed the usual relationship between ruffled and these genes.

#### NEW CHARACTERS IN *DROSOPHILA VIRILIS*

For the use of other geneticists, the following list of mutants recently discovered in *D. virilis* by Demerec and associates is herewith made of record.

"Characters found recently in *Drosophila virilis* are the following: maroon (*mr*) eye color, sex-linked recessive, located 3.3 units from forked and 4.6 units from miniature; plum (*pl*) eye color, sex-linked recessive located in the neighborhood of small bristles; puffed (*Pu*) eye texture, second chromosome, dominant, located 26.4 units to the right of confluent; short veins (*sv*), third chromosome recessive, located 24.8 units from telescoped and 23.5 from garnet; cardinal (*cd*), light eye color, third chromosome recessive, located one unit from garnet; reduced (*Rd*) veins, fourth chromosome dominant, giving no crossing over with glossy among 2968 flies; peach (*pe*), recessive eye color, the first locus at the left side of the fifth chromosome; short vein fifth (*Sv-5*), fifth chromosome dominant, located 46.4 units from peach and 29.3 from interrupted; wingless (*wl*), fifth chromosome recessive; clipped (*Cl*) wings, sixth chromosome dominant."

#### DATURA

Gene mutations, by virtue of which new hereditary characters are introduced into a species, have a frequency of occurrence that is directly proportional to the time and thoroughness of the search made for them. In general, there are three methods relied on to secure them. First, the



method of extensive collection of individuals, or seeds, over as wide an area as possible, or through the intensive collection of individuals over a smaller area. By the latter method, Shull, years ago, collected at Cold Spring Harbor some scores of biotypes of shepherd's purse, previously quite unrecognized. Second, the method of breeding horticulturally great numbers of individuals and examining and comparing them closely. This has been the favorite method of the great plant breeders; for example, Burbank, who each year raised many thousand ("millions," he called them) individuals of the species in which he was, at the time, interested. Third, the method of inducing gene mutations by the use, at present, of X-rays and radium. But this method results also in chromosomal changes.

It is now 13 years since this Department entered seriously into the *Datura* problem. Although *Datura stramonium* had been much worked with by the early hybridizers, had been used by De Vries in his studies leading to the re-discovery of Mendel's law and had formed the basis of an extended report to the Evolution Committee by Bateson and his collaborators, only two Mendelian character pairs were known in this species when the Department began its genetic investigation of *Datura*. All told, there have appeared in Blakeslee's cultures over 160 characters that are provisionally classified as genes. A few of the groups may be mentioned. There are 20 albinos, one of which has been located in the 13 half of the 13-14 chromosome. These albinos, like other types that die in the seed pan, generally must be bred in the heterozygous condition, though with great difficulty some may be grafted and used homozygous. A near albino that is able to survive in the seed pan and grow further is called pale. We have 15 pales of which two have been located, one in the 21-22 (Gl) chromosome and the other in the 15-16 (Rd) chromosome.

Five different kinds of male-sterile mutants have turned up. One of these, a dominant, has been located in the 9-10 (Ec) chromosome by two methods. Since this MS-1 has no pollen it could not be used as male in crosses. Consequently it was used as female in crosses to certain prime types used as pollen testers. Crossed with prime types in which the 9-10 (Ec) chromosome is present and interchanged with another, and only in such, and the female offspring back-crossed to Line 1, plants with 50 per cent bad pollen resulted. Hence it is concluded that MS-1 is located in the 9-10 chromosome. Again, a MS-1 plant was found by Blakeslee to have mutated to a tetraploid. This female crossed to a  $2n$  gave a male-sterile  $3n$ . A female of the latter back-crossed to  $2n$  gave some male-sterile  $2n + 9-10$  (Ec) plants, as well as other primaries. Such  $2n + 9-10$  plants produced in their offspring trisomic ratios for male-sterile, thus again demonstrating that the male-sterile gene lies in the 9-10 chromosome. Of the remaining 4 recessives, 2 are female-sterile.

Abortion of half the pollen grains without abortion of the egg-cells is known in 9 cases and is probably due to genes lethal only to the pollen grains affected. These genes are called half-male-sterile (HS). HS-1, discovered in a race from Japan, has been located in the 19-20 chromosome by means of crosses with PT 7 and PT 8. Hs-4, apparently, is in the 3-4 (Gs) chromosome, since it appears to be linked with bronze which is in this chromosome.



A group called rough, or glaucous, from the appearance of the leaves, is made up of 8 types. One of these behaves as a dominant character, linked with a chromosomal complex due to translocation between the 1·2 and the 11·12 chromosomes. However, the possibility must not be overlooked that in this, as in some other cases, the morphological effects may be attributed to chromosomal excess, or deficiency, rather than to a single gene linked to a chromosome of the new complex.

We have 15 or 16 types involving pollen form, or behavior, which are classified as due to genes. A recessive (Baltimore bad) located in the 21·22 (G1) chromosome inhibits conjugation of chromosomes at meiosis. A recessive that is probably in the 19·20 chromosome was isolated in a race from Hungary; it causes doubling and twinning of chromosomes at meiosis, leading to giant pollen grains containing as many as 96 chromosomes. A recessive discovered by S. Horowitz last summer, from X-rayed material, produces giant pollen grains through dyad, instead of the usual tetrad, formation. Another type has half of the pollen grains without starch; the gene for the light grains is not transmitted through the pollen. Still other types have compound grains, bean-shaped grains, grains with premature germination, etc. Finally, into a miscellaneous group Blakeslee puts some 90 or more types of which the majority at least are probably to be classed as due to genes. The genes, as isolated, serve as markers for chromosomes and parts of chromosomes.

#### PRIME TYPES (PT's)

These have been defined in the last Year Book as chromosomal  $2n$  races, which are homozygous for one or more interchanged, or translocated, chromosomes. Up to the present, Blakeslee, Bergner and collaborators have discovered 57 prime types; and in 33 of these the modified chromosomes have been already determined. Among these are chromosomal testers for all of the chromosomes except one. Indeed, translocations and interchanges are so frequent in radiated material that economy is now necessary in their isolation. Some induce 25 per cent or 50 per cent aborted pollen when heterozygous. These can be isolated by pollen determinations and the tedium of cytological study avoided. Once isolated, the chromosomes involved may be determined by cytological study of hybrids with appropriate chromosomal testers. By use of compensating types, pollen testers or genes, the chromosomes involved can be determined entirely without cytological work. Prime types are of value as chromosome and pollen testers and as source of tertiary ( $2n + 1$ ) types and of compensating types. Of especial interest is the possibility which a large collection of prime types affords of synthesizing new pure-breeding types.

#### SYNTHESIZED PURE-BREEDING TYPES

The late William Bateson used to emphasize the point that modern genetics was not throwing light upon the origin of species. The new knowledge concerning segmental interchange between chromosomes does have bearing on that matter. As Blakeslee has pointed out, the most satisfactory criterion of a species would be morphological distinctness from other species in respect to more than a single character and a degree of

constancy in reproduction. The  $2n + 1$  chromosomes lack the element of constancy. The prime types and certain other chromosomal types, on the other hand, do breed true and might become the progenitors of synthesized pure-breeding types. Blakeslee's group of investigators has made most progress with the 1·2 chromosome and they have obtained homozygous types similar in appearance to the secondary  $2n + 2\cdot2$ , which has extra ·2 halves. Success depends upon the fact that the extra ·2 half, one or both, can be transmitted through the male.

The first pure-breeding type has 24 chromosomes and is homozygous for the chromosome 2·11·12, in which the ·2 fragment is permanently attached to the 11·12 chromosome. It has bred true for several generations. The second type is a compensating type with 26 chromosomes homozygous for the secondary chromosome 2·2 and for the fragment ·1. The third type resembles in appearance the other two types. It has 26 chromosomes and is homozygous for the modified chromosomes 2·14 + 13·23 + ·24. It should breed true. It seems probable that, in time, other pure-breeding chromosomal types may be synthesized. Though these laboratory species are artificial, they render it not improbable that their counterpart may some time be found in nature.

#### SPECIES IN NATURE

The possibility that species may have arisen in nature by the same processes as have produced our artificial species is supported by the analytical study of chromosomal differences in *Datura*, both from the standpoint of intraspecific and interspecific differences. These studies have been made by Dorothy Bergner.

Intraspecific differences between the races of *Datura stramonium* have been found in a study of about 550 races from nature. Five types have such relation of chromosomes to each other that they are interpreted as having arisen by interchange of segments between chromosomes. It is indeed probable that such segmental interchange is of widespread occurrence.

Interspecific chromosomal differences have been further studied. It is now possible to state the differences in the ends of chromosomes in the 3 related species, *D. stramonium*, *D. quercifolia* and *D. ferox*, in terms of the races used as standard testers. Remembering that in our standard species (*D. stramonium*) the chromosome halves are numbered: 1·2, 3·4, . . . . 23·24, for the 12 chromosomes, one sees what new combinations of part chromosomes have been made in other feral species. Thus both *D. quercifolia* and *D. ferox* have the chromosomes 1·18, 2·17, 11·21<sup>21</sup> and <sup>12</sup>12·22 instead of the stramonium chromosomes 1·2, 17·18, 11·12<sup>12</sup> and <sup>21</sup>21·22 (the super-numbers indicating humps or satellites). *Quercifolia* has the chromosomes 7·20<sup>20</sup> and 19·8<sup>8</sup> and *ferox* the chromosomes 7·20<sup>16</sup> and 15·16<sup>20</sup> instead of the stramonium chromosomes 7·8<sup>8</sup>, 19·20<sup>20</sup>, and 15·16<sup>16</sup>.

When these species are crossed *inter se*, new chromosomes are sometimes formed by segmental interchange. Thus in the *stramonium-ferox* hybrid the two new chromosomes, 7·20<sup>20</sup> and 19·20<sup>16</sup> are obtained. *D. leichhardtii*

has been crossed with *D. stramonium*, *D. innoxia*, *meteloides* and *pruinosa*. So far chromosomal configurations apparently due to segmental interchange have been found in 8 different *inter se* hybrids in *Datura*. Segmental interchange has, therefore, probably taken place in the differentiation of these species.

#### POLLEN-TUBE GROWTH

Dr. John T. Buchholz has continued his study of pollen-tube growth. He finds that there are certain recessive genes which delay pollen-tube growth. In consequence these types can not ordinarily appear in the homozygous condition. By limiting the number of pollen grains placed at one time on the stigma, he has been able in one case to obtain plants homozygous for the slow-growing tubes. They constitute a morphologically distinct and novel form. In combination with C. C. Doak he has devised a still more effective method of securing the transmission of these recessive genes. This method consists of cutting out the portion of the style containing the most advanced normal tubes and grafting on the upper part of the style which contains the slow-growing tubes. The latter were thereupon found to function despite the surgical operation.

#### TISSUE CHANGES IN CHROMOSOMAL MUTANTS

With the assistance of Helen Houghtaling, Dr. E. W. Sinnott has been carrying forward his study of the tissue changes induced by extra primary and secondary chromosomes. By plotting the + and - deviations from the condition in normal  $2n$  plants, for some 30 different tissue characters, he finds in some cases that the primary type is intermediate between its two secondaries, as was to have been expected. But in other cases, the primary is more extreme than either of its secondaries. This fact points to complementary factors in the two halves of a single chromosome and brings added evidence for the conclusion that the normal assemblage of genes within the organism intimately interact.

#### CLADOCERA

Banta has continued, with the assistance of Miss Wood, the study of the mutants that are revealed by inbreeding clones of *Cladocera* which have long been carried parthenogenetically. These mutants are largely physiological; among these mutants are dwarfs, referred to in last year's report. At that time fertilized eggs had been produced from them. Over 100 hatches have, at the time of the present report, been obtained. The breeding results, so far, are as follows. Dwarfs inbred and crossed have produced 10 viable offspring, all dwarfs. Crossed with normals the  $F_1$  generation comprised only normals. The  $F_2$  inbred were 11 normals and 5 dwarfs; these mated *inter se* produced 14 normals to 5 dwarfs. Despite early mortality and sterility the hatches yielded sufficient number of viable individuals to support the conclusion that dwarfness is recessive and that a single, principal genetic factor is involved. There are, however, probably accessory factors influencing dwarfness and there is the further complication of slow developers that are not dwarfs.



## DETERMINATION OF SEX

CONTROL OF SEX IN *MOINA MACROCOPA*

For many years, now, Banta and Brown have been trying to get a satisfactory explanation of the fact that the daphnid, *Moina*, produces males when they are crowded in the bottle; and they have drawn Dr. C. A. Stuart of Brown University into the problem. Stuart was inclined to think of the experiment in terms of nutrition—the more mothers per bottle the less food for each. To test this view, a homogeneous bacterial suspension was made up and from it 4 different dilutions, *viz*, 1/15, 1/25, 1/50, 1/100. Each of these 4 dilutions is then placed in 4 similar bottles, the volume of the fluid in each varying but the total bacteria remaining the same. The same number of daphnids is placed in each bottle, and each daphnid has the same absolute amount of food (though in varying dilution). In the sum total of the 4 bottles of each dilution the daphnids produced on the average about 35 per cent males, but if we consider the average male production in the 4 bottles of each of the 4 different volumes the result is very different. As the volume increases the proportion of males increases. At the 1/15 dilution the increase with volume was from 11 per cent to 62 per cent; at 1/25, from 24 per cent to 53 per cent; at 1/50 from 4 per cent to 61 per cent; and at 1/100 dilution from 17 per cent to 44 per cent males. Thus, volume is quite as important a factor as total number of bacteria available as food, or even their concentration.

The second type of food and crowding experiment was run in duplicate. In one series the food concentration was low; in the other high. At each food level the mothers were crowded in different degrees. In each series the proportion of males increased with the crowding—there was control of sex by crowding. On the other hand there was somewhat increased male production in the low food-concentration. Thus:

No. of mothers per vial	Per cent male, higher food	Per cent male, lower food
1	0	0
2	9	35
4	35	42
6	41	50
8	51	61

This shows, also, the limiting effect of food concentration.

Banta is inclined to conclude that the amount of available food and the temperature, as reported last year, constitute general or limiting factors. Thus *Moina* mothers will ordinarily produce only males below, or above, a certain number of bacteria per ml. As for temperature, there are two temperature intervals that favor male production. Given food concentration and temperature favorable to male production, then the percentage of males produced is proportional to the amount of crowding.

CRITICAL PERIOD FOR SEX CONTROL IN *M. MACROCOPA*

While earlier studies by Banta and Brown indicated that 4 hours before egg-laying was the critical point at which sex was determined by environ-

mental factors, yet they later showed (Year Book, 1931, p. 53) that temperature had a larger effect, if applied for longer periods of the pre-adult life of the female. Recently Banta and Stuart have found that the effect of low food-concentration applied temporarily as much as 9 to 14 hours before egg-laying, followed by high food-concentration, will still show itself by high male production. It is thought that the longer continuation of the low temperature helps to build up a male-inducing situation within the ovarian egg and that it takes a prolonged abundance of food to overcome the effects of the earlier scarcity, which had affected the ovarian eggs in a male-inducing direction. The critical period for the *internal* environment (that of the egg itself) is probably 4 hours before ovulation.

#### THE SIGNIFICANCE OF SEXUAL EGGS IN CLADOCERA

Sexual eggs not only, by their high resistance, bridge over unfavorable conditions in the environment, but produce new genetic combinations, of which some have an especial, survival value, like the thermal clone and clones possessed with exceptionally high vigor and reproductive capacity. Banta has some general ideas on this subject, the outgrowth of his 22 years' experience with the Cladocera.

"Long-continued parthenogenesis results not only in the accumulation within a clone of recessive mutations but also (tho infrequently) in the occurrence of dominant, or partially dominant, mutations. The excavated head and other morphological characters are such. Further (and not too infrequently) a clone after a period of parthenogenesis may suddenly (or progressively) show lessened vigor. Such a clone may ultimately 'recover' its former vigor. More often, however, the lessened vigor persists, or increases, and the clone ultimately dies out, or is discarded as an unsatisfactory line. Such permanent loss of vigor, it seems to us, is most logically explained as due to a semi-lethal mutation which is semi-dominant, or dominant. Many clones of *Daphnia longispina* (which is our Cladoceran species in which mutations seem most common) and some other clones have sooner or later shown evidence of such mutations.

"In the wild, a mutating Cladocera stock might readily perish but for the occasional occurrence of sexual reproduction and the resulting favorable re-combinations. Doubtless, too, the 'rejuvenation' of protozoa by conjugation, or endomixis, is a similar phenomenon.

"The *Moina macrocopa* sexual eggs which promptly hatch (as just described) might readily produce some genetic re-combinations better adapted than the old parthenogenetically reproducing stock to continue the species in the habitat in which sexual reproduction was occurring."

#### A MODIFICATION OF GAMOGENESIS IN MOINA AFFINIS

Usually a pair of sexual eggs is formed, one in each ovary. Miss Wood has, however, found a strain of *Moina affinis*, from Indiana, which produces at a time only a single sexual egg. If a male is present and fertilization takes place the sexual egg is soon laid; otherwise, it degenerates in the brood chamber. In the latter case there may develop in the opposite ovary from that furnishing the sexual egg and in the same instar some parthenogenetic eggs. In lines where a sexual egg is produced in each ovary, parthenogenetic eggs do not begin to develop until the following instar.



## TIME OF EGG-LAYING AND LENGTH OF THE EMBRYONIC PERIOD

The time elapsing between generations is in *Moina macrocopa* about 10,000 minutes. A statistical study shows that mothers that produce females lay their first clutch of eggs, on the average,  $11.77 \pm 1.68$  minutes later than mothers that produce males. The length of the embryonic period is  $24.33 \pm 2.06$  minutes longer for male than female embryos. Thus, on the average, the mother which is giving birth to her first clutch of male young is about 12 minutes older than the mother producing her first clutch of female offspring.

THE TECHNIQUE OF SECURING AND HATCHING SEXUAL EGGS  
OF DAPHNIA LONGISPINA

Until a few years ago the sexual egg of Cladocera was a somewhat uncommonly noted phenomenon and its hatching was regarded as fairly rare. Miss Wood has developed a successful technique for securing and hatching them in the laboratory. Of 13,450 eggs secured so far from controlled matings during the eight years the work has been in progress, 2630 have hatched.

The problem of securing the sexual eggs involves not only inducing their production but also securing their fertilization at the proper time by males of the desired pedigree whose production must also be controlled. The technique was to place 15 to 18 newly released females at room temperature in 180 c.c. of manure infusion, adding a little more of the infusion after 5 to 7 days. Males and sexual eggs are produced; the latter being fertilized by the males. The sexual eggs must be dried before they will hatch. After 10, and again at 20, days dilute, filtered medium is added. However, as stated in last year's report there are clones of *Moina macrocopa* that hatch without a latent period. These resemble the grasshopper eggs that Bodine found able to hatch without a resting stage and which were accordingly adapted to continue the species in mild climates.

## THE RÔLE OF THE ENDOCRINES IN DEVELOPMENT

## MICE

Studies reported earlier by MacDowell have shown that dwarf mice have rudimentary, or highly defective, anterior pituitaries, thyroids, adrenals and gonads. Also, last year evidence was found that the pituitary control of the thyroid was primary and irreversible. As a further test of this conclusion a biological assay has been made of the anterior lobe of the pituitary in dwarfs whose growth had responded to thyroid feeding. First, Mr. T. Laanes fed thyroid to 30 dwarf mice, which, after 20 weeks, had attained the weight of 20 to 35 grams. Thereupon Professor P. E. Smith, who is collaborating in these experiments, transplanted the pituitaries of these growing dwarfs into a single, previously untreated, dwarf at the rate of two pituitaries per day. As controls for this experiment, one dwarf brother was treated with one normal anterior lobe a day; another dwarf brother was treated daily with anterior lobes from 4 untreated dwarfs, and a fourth dwarf brother was held entirely without treatment in the same cage. The failure of growth from treatment with glands of the thyroid-fed dwarfs indicates the failure of the thyroid extract to stimulate the produc-

tion of the growth hormones, while the failure to respond to the intensive treatment with untreated dwarf glands adds further evidence for the conclusion that the growth hormone, if not entirely absent, is extremely deficient.

A remarkable outcome of the treatment of dwarf mice with normal anterior lobes is that, even 8 months after treatment is suspended, the dwarf, although never reaching full size, is fertile and sires large litters.

Dwarfs have been used by Laanes in a test of treatment with a highly purified, crystalline extract of the adrenal cortex, prepared and supplied by Dr. R. L. Zwemer of the College of Physicians and Surgeons. Contrary to all expectations, a very carefully controlled experiment, based on 9 dwarfs treated three times a day for a month, gave entirely negative results.

#### PIGEONS

##### A THIRD HORMONE OF THE ANTERIOR PITUITARY

It becomes constantly clearer that, in the higher animals, the genes do their work in part by directing the development of organs that direct the later stages of development. This mechanism appears most plainly in the endocrine organs; and the endocrine organs do their work through the hormones that they elaborate and send out into the blood stream to play particular rôles in metabolism and development.

This year two capital discoveries have been made concerning the rôle played by certain hormones secreted by the anterior pituitary gland. From this gland was first obtained, in 1921, by Evans and Long, a "growth" hormone; and a "maturity" or "gonad stimulating" hormone was identified in this gland by P. E. Smith and by Zondek and Aschheim in 1926. It had also been shown that the anterior pituitary secretion is necessary to the stimulation of the mammary gland to produce milk. Next, as reported last year, Riddle and Braucher showed that the development of the crop glands, with crop-milk formation, in pigeons, depends on something produced in the anterior pituitary gland. Riddle, Bates and Dykshorn have now isolated a third distinct hormone from this gland and this they call prolactin. In birds it is the special agent that induces crop-gland formation and its active functioning.

The demonstration of this conclusion rests on a series of intra-muscular injections of anterior pituitary preparations into ring-doves and pigeons. A good type of "growth" hormone, given at the rate of about 0.4 c.c. a day, produced no increase of the crop gland from the quiescent weight of about 100 mg. Also the pure gonad stimulating principle shows no effect. Doses of "antuitrin" (anterior lobe) have no effect, but prolactin has a powerful effect, increasing the weight of a single crop gland to 900 or 1000 mg. At the same time the testes do not respond at all, as they do to the maturity hormone.

After this discovery it was natural to apply it to mammals also, to see if prolactin is the hormone responsible for stimulating milk secretion in them. Accordingly, prolactin was injected into non-pregnant guinea-pigs and rabbits. After 3 to 5 days they began to lactate. In less mature females and in males, a preliminary treatment with theelin, or progesterin, was necessary and, when this was followed by prolactin, milk was secreted after the

lapse of 4 or 5 days. But when purified growth and maturity hormones alone were injected no lactation occurred. Riddle and Bates found, as would be expected, some irregular results, perhaps due to some ovarian hormones.

As the method of preparation of the newly isolated hormone will be of interest to those who may wish to repeat the experiments this is given herewith:

Frozen anterior pituitaries of beef or sheep were ground, defatted with acetone and alcohol and dried. This powder was extracted three times in aqueous medium at a pH of approximately 2.5. The acid extracts were precipitated isoelectrically. The isoelectric precipitate was redissolved and precipitated three to five times to free it of maturity hormone and dried with acetone. About 10 per cent of the original weight of dried powder was thus obtained in an acid-soluble, isoelectric-insoluble form. The injection of slightly less than 1 mg. of this substance on each of 3 or 4 successive days gives a definite response in the crop gland of a dove. The addition (to suspensions) of 0.2 per cent cresol to complete the destruction of the growth principle does not markedly affect the "prolactin."

#### CROP-MILK

Since crop-milk produces a phenomenally rapid growth of pigeons to which it is fed, attention has been directed to the nutritive, vitaminal and hormonal properties of this substance. At the request of Riddle, two Research Associates of the Institution, Professor Lafayette B. Mendel, of Yale University, and Dr. Hubert B. Vickery, Connecticut Agricultural Experiment Station, have taken up and concluded studies on the vitamin A and B content of crop-milk, supplies of this material having been prepared for them daily at this laboratory by Bates. The results reveal the presence of both vitamins A and B, but not in unusual, or especially significant, amounts.

### PHYSIOLOGY OF SEXUAL REPRODUCTION AND DEVELOPMENT

#### METABOLISM OF DOVES AND PIGEONS

While the genes themselves are rather resistant to the influences of environment they determine the development of the endocrine glands which are decidedly sensitive to environmental conditions. On this point Riddle's studies, done in collaboration with Dr. Benedict, and with the assistance of Mrs. Guinevere C. Smith, are of importance. As a result of 413 measurements made on a single race of common pigeons, some held at 15°, some at 20°, and some at 30°C., and all at various seasons of the year, it appears that the seasonal state of the animal markedly influences the value of the metabolism at whatever environmental temperature this metabolism is measured; the metabolism being highest when the animals have been currently exposed to cold (autumn). In the summer, as the temperature used for the measurement is lowered, this increase in metabolism first becomes marked at below 20°C., while in the cool autumn the increase is more nearly uniform and less per degree in passing from 30° to 15°. Thus the so-called "critical" temperature apparently varies with the seasonal and endocrine state of the animal.



Not only does the metabolism of pigeons change with temperature, but also with the internal states that accompany age. Others have shown that soon after birth the human infant has a relatively low metabolism; while at 4 or 5 years it attains the highest metabolism of the life cycle. In pigeons, our collaborative studies show that, at an age while it is still a cold-blooded animal, there is shortly after hatching a period of low basal metabolism, followed, at about 11 days, by a period of very high metabolism. This confirms an earlier report by Kayser and Ginglinger. It is remarkable and, at present, quite inexplicable that the low metabolism occurs when the pigeon is in a period of most rapid growth and increases for a short period as the growth is slowing down.

This difference in basal metabolism shows itself also in different species. Thus the migratory, cold-avoiding mourning dove has a higher metabolism than have related non-migratory domesticated doves and pigeons. This metabolism appears not to respond to cold weather, contrary to the case of domestic pigeons; and this may be related to their migratory habits, by which they avoid cold weather. This peculiarity of the mourning dove reappears in the hybrids between it and the Zenaida dove (whose metabolism is lower).

#### STUDIES IN PHYSIOLOGY IN RELATION TO RACE AND SEX

##### OXYGEN CARRIERS OF THE BLOOD

With the assistance of Miss Pela F. Braucher, Riddle has accumulated a large body of data on the variation in the quantity of hemoglobin and red cells in the blood of the two sexes of pigeons in different races and at different seasons. It appears that in both ring doves and in common pigeons the number of erythrocytes (red blood cells) and the amount of hemoglobin per 100 c.c. of blood is greater in the male than in the female at all seasons of the year. Since the oxygen carriers of the blood fluctuate quantitatively with the oxygen demands of the tissues, this greater quantity of oxygen in the male reflects the excess demand of the male tissues over those of the female. These facts are in accordance with the theory, established by Riddle's prolonged researches and those of others, that in the male metabolism takes place faster than in the female, and that this difference is a primary sex difference in egg, embryo and adult.

This theory is further supported by another group of facts. In the pigeon-dove colony were found some 30 birds, with ovaries which at an age months beyond the normal age for the start of egg laying had never begun to discharge eggs. These retarded, or sterile, females showed, on the average, a probably significant excess of hemoglobin and red cells over adult, normally functioning females of the same race—thus resembling males of that race.

The number of erythrocytes and the quantity of hemoglobin in the blood also shows a certain relation to season. Thus, the number of erythrocytes is constantly lowest in summer and highest in autumn, when our pigeons experience their lower external temperatures. Roughly, but not quite so definitely, the same rule holds for quantity of hemoglobin.

INTERSEXUALITY IN MOURNING DOVE  $\times$  RING-DOVE HYBRIDS

It has long been known that in crosses of pigeons belonging to different families only male offspring develop. The mourning dove and the ring-dove belong to different sub-families. From a mourning dove male and a ring-dove female the hybrids were, in 44 cases, studied in respect to sex. Among 21 dead or killed at hatching 16 were clearly males and 5 had nearly the appearance of females. Of 23 that were reared to maturity, 18 were definitely males. The remaining 5 were alike and of special interest. In each, at the site of the left germ gland (the normal site of the ovary) was a small, discolored, rudimentary degenerate mass, quite devoid of ova, but containing testicular tubules. Each had a small oviduct on the left side. These are interpreted as genetic, but not functional, females. They form a new link in the chain of sex intergrades found in the progeny of wide crosses, of which another link consists of males with left oviducts persisting.

## RELATIVE VELOCITY OF GROWTH IN RACES OF LARGE AND THOSE OF SMALL PIGEONS

Recently, Castle and Gregory have shown that cell multiplication is more rapid in the early embryonic stages of races of large rabbits than of small ones. With the aid of Mr. Donald R. Charles and Mr. George E. Cauthen a comparative study of this problem was made by Riddle on our largest and smallest races of pigeons. The weights of embryos of these different races showed that racial size difference is only very imperfectly expressed during embryonic life. But in the post-hatching period, size difference becomes accentuated by a differential growth rate and practically all of the adult size difference is attained before maturity. Riddle concludes that while it is still uncertain to what extent endocrine (pituitary) differences determine rate of cell-growth at any particular developmental stage it is wholly probable that such endocrine difference is an effective factor in higher animals at some stage.

Riddle, with the assistance of Miss Theodora Nussman, has found that, on the average, female pigeons and ring-doves have both longer intestines and larger anterior pituitary glands than males of the same race, though the females weigh significantly less than the males. This finding supports his view that the pituitary secretion influences length of the intestine. It has been shown by others that in man and rats the pituitaries are larger in females than males; so, this wide-spread pituitary difference may represent a fundamental sex difference.

## CHROMOSOMES IN PIGEONS, DOVES AND THEIR HYBRIDS

The importance of a knowledge of chromosomes for the interpretation of the results of hybridization has led us to seek the cooperation of Professor Robert T. Hance of the University of Pittsburgh in this study. He started work at Cold Spring Harbor and is still continuing his studies at Pittsburgh. Though the difficult task is still unfinished, Dr. Hance has furnished for this report the following statement:

"The chromosomes of 'the pigeon' are greater in number but rather more favorable for study than are those of the domestic fowl. The metaphase



plate shows the chromosomes in much the same size variations as were found in the chick. The number of chromosomes will perhaps always be difficult to determine with accuracy, although the Japanese student, Oguma, reports 62 as the typical male number. My counts on material that is as well preserved as Oguma's have seldom risen much over 50 and in the few cases in which 60, or more, chromosomes were found, fragmentation was rather clearly indicated. As in the case of the chick the male pigeon has two chromosomes longer than the others, while the female has but one of equivalent length. These observations agree with those of Oguma and it seems very likely at present that these longest chromosomes are the ones associated with, if they are not the actual determiners of, sex."

## GENETICS OF SPECIAL TRAITS

### LEUKEMIA IN MICE

#### CYTOLOGICAL STUDIES

The cooperative group working under a grant from the Carnegie Corporation of New York on mouse leukemia in this Department and in the Department of Pathology of the College of Physicians and Surgeons in New York has been strengthened by the addition of James S. Potter, a cytologist, at Cold Spring Harbor, and Joseph Victor, a cell physiologist, in New York. In both new fields important discoveries have been made. The cytological studies have established a fundamental basis for the classification of the disease leukemia as a form of cancer.

Studies cited in earlier reports have shown that living cells are required to transmit the disease. But the possibility remained that within the host the inoculated cells transfer some agent responsible for the leukemic phenomena to cells of the host, while they themselves die. In such case the cell lineage of the infiltrating cells, in successive transfers of an inoculation line, would be discontinuous, instead of uninterrupted as is the case with true cancer. If indeed the inoculated cell is the unit, its leukemic properties may be due to changes in the mechanism responsible for all hereditary traits. These cytological studies, as well as the organization of the laboratory for microscopical preparation, have been carried out by Potter, with the assistance of Margaret D. Findlay and Phyllis V. Plyler.

In tracing the origin of the infiltrating cells that follow the inoculation of a susceptible mouse it is necessary, first of all, to establish the identity of the leukemic cells. In a given inoculation line the predominating cells accumulated in all lesions of the inoculated mouse have the same features, but these sometimes are found in normally occurring cells. The only constant difference found was in a precocity of the process of chromosome-splitting before metaphase. There are, however, certain differences between the leukemic cells of the different inoculation lines; for example, between Lines I and L. Thus, in Line I the leukemic cells are large, basophilic, usually irregular and with 30 or more mitochondria. In Line L, on the other hand, such cells are smaller, less basophilic, more rounded. Also, in fields consisting entirely of infiltrations, Line I gives an average of 6.7 per cent of cells in a recognizable phase of division, while Line L gives 3.7 per cent of such cells.

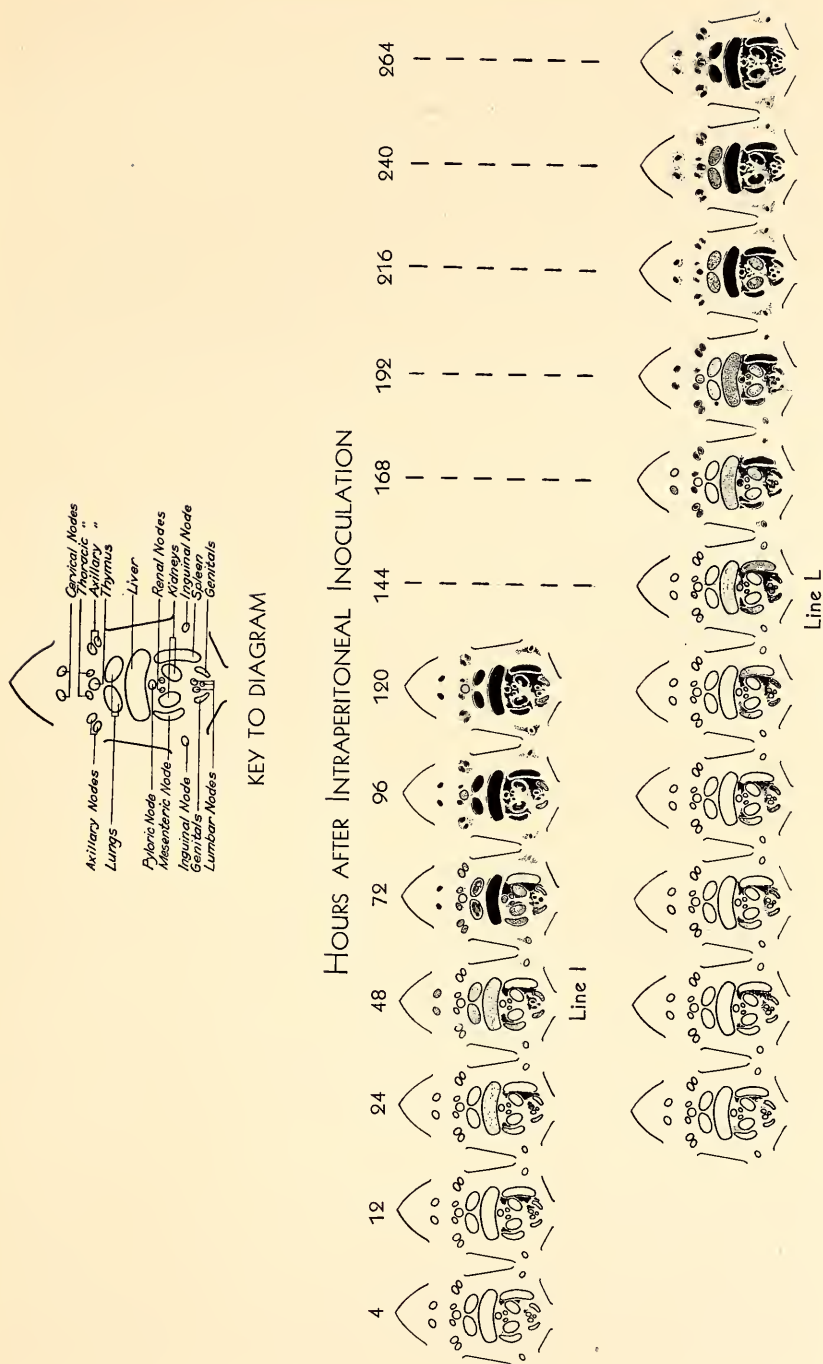


FIG. 2

The second step in tracing the origin of the infiltrating cells was to follow the inoculated cells from the moment of inoculation until the death of the animal. In each of three transfer generations of Lines I and L a series of animals was killed at regular intervals following inoculation, done sometimes intraperitoneally and sometimes into the thigh muscles. In the latter class, the inoculation was confined more closely and its spread more readily traced. For this purpose the nodes and organs of 172 mice were studied in serial sections. Thus the behavior of the inoculated cells was followed step by step and the development of the lesions was observed as in a moving picture. Many of the inoculated cells disintegrate, but many survive, penetrate the host tissues and proliferate by division. Cells of Line I (where cell division is most rapid) are disseminated and establish lesions throughout the host about twice as rapidly as cells of Line L, although the path from a given site of inoculation is the same (fig. 2). The mice inoculated with Line L cells live twice as long as those inoculated with cells of Line I.

The third step was to study the lymphoid tissues of the host to determine whether the germinal centers of these tissues had been stimulated to greater activity and to the production of cells of the type characteristic of the line. No evidence of such activity was found. The descendants of the inoculated cells could be shown to enter the lymph nodes, spleen, etc., and not to originate within them.

Since it is possible to trace the injected cells and their descendants to the formation of lesions and since the lymphoid tissues of the host do not become active in the formation of the type cell, the conclusion is reached by Potter that the cells of a given line form an unbroken lineage of descent from transfer to transfer, that they are direct descendants of the cells taken from the original mouse with spontaneous leukemia that started the transmission line.

#### CARBOHYDRATE METABOLISM

Workers with tumor tissue have demonstrated an increase in aerobic and anaerobic glycolysis in such tissues as compared with normal. Furthermore the difference between malignant tumors and normal tissues is greater than that between benign tumors and normal. An explanation of this altered metabolism has been found to a certain extent by the demonstration of the inability of malignant tumors to oxidize lactic acid. Investigation of the agents that alter metabolism of normal tissues to that of malignant tissues may throw considerable light on the agent concerned in malignant growth.

In view of these important studies, Joseph Victor has undertaken the investigation of the metabolism of leukemic tissues from spontaneous and inoculated cases.

In these experiments the oxygen consumption and aerobic and anaerobic glycolysis were measured by means of the Fenn respirometer. Ringer's solution was used as the bathing medium. In the aerobic experiments the oxygen tension was 95 to 100 per cent, depending upon the presence of CO<sub>2</sub> in the gas. Five per cent CO<sub>2</sub> was used in the glycolysis experiments.

Ninety-five per cent  $N_2$  was used in the anaerobic measurements. The temperature was  $37.5^{\circ}C. \pm 0.005^{\circ}$ .

Compared with normal lymph nodes, the carbohydrate metabolism of leukemic nodes has a higher oxygen consumption than aerobic and anaerobic glycolysis, which both increase with the chronicity of the disease. The relative increase in metabolism is found to be greatest in the anaerobic glycolysis and least in oxygen consumption. Further experiments will have to decide whether this change with chronicity is due to a physiological change in the leukemic cell or to the increase in their number. Metabolism of leukemic tissue resembles that of benign tumors and approaches that of malignant tumors as the duration of the disease is prolonged. The increased oxygen consumption associated with an increased aerobic lactic acid production suggests that lactic acid may play a rôle in stimulating the respiration of lymphoid tissue or of leukemic lymphoid tissue.

#### INHERITANCE OF SPONTANEOUS LEUKEMIA

As has been stated previously, the first generation hybrids between the leukemic strain C58 with which MacDowell is working and the non-susceptible strain StoLi show susceptibility to spontaneous leukemia; indeed, over half are leukemic (while in the uncrossed leukemic strain 90 per cent are leukemic). The genetic differential between the two strains that influences the occurrence of leukemia is, accordingly, not a recessive gene. Since in the  $F_1$  generation 56 per cent are leukemic; in the back-cross  $F_1 \times$  resistant strain, 43 per cent; and in the  $F_1 \times$  pure leukemic strain, 53 per cent; one must conclude, that there is partial dominance of a complex genetic control interacting with factors not under specific genetic control.

*Changes in transmission lines*—Six transmission lines have been maintained throughout the year and the number of transfer generations now ranges from 53 in Line L to 203 in Line I. As MacDowell puts it:

"In view of the continuity of cell lineage now demonstrated, these lines may be spoken of as cultures of independent somatic cells that have lived parasitically for periods of 2 to nearly 4 years in the mice successively inoculated. This experience has led to certain general conclusions.

"(1) Characteristically, during the course of the early transfers, the virulence of the disease, judged by the time the hosts die, increases rapidly and then maintains a uniformity over long periods of time. Though they differ in the rate of this increase, all lines tend to become stabilized when the minimum interval till death reaches 7 to 9 days. In a few cases where deaths in the first transfer were unusually rapid, the characteristic increase in virulence did not occur and the later history shows no unusually high virulence.

"(2) Lines that have become stabilized show characteristic degrees of variability in the death intervals of individual hosts in the same transfer generation.

"(3) Lines long showing constant virulence may eventually change their virulence. Thus, Line I was highly uniform during the 16 months in which it was being used for the analysis of the genetics of susceptibility. Subsequently a change has taken place that is expressed in virulence as well as other ways. Death now occurs in 4 to 6 days instead of 6 to 8 days;



the excessive infiltration of the abdominal muscles is something novel. Potter finds the number of mitochondrial cell inclusions to have increased from about 20 to over 30. Furthermore, the cells of this line will now develop in the strain of mice that was previously negative (StoLi), but the interval before death is longer than in strain C58 and some of the animals are able to eliminate the disease after the inoculated cells have undergone considerable growth. Correspondingly, back-crosses and the  $F_2$  generation no longer give evidence of segregation in respect to susceptibility."

The origin of the various characteristics of the cells and of their activities in the different lines and the nature and control of the changes that they show stand out as major problems. MacDowell suggests the hypothesis that they are due to a selective process working upon individual genetic differences between cells.

"The process of injecting suspensions of minced spleen into a mouse at each transfer provides a selective basis. Large numbers of cells die; the descendants of those cells that survive the passage and are best qualified to grow in their new environment will predominate in the host tissues and the succeeding transfer will start with a more uniform and more potent population of cells."

This raises the question of the possibility of genetic variation among the leukemic cells of a spontaneous case. As a test of this possibility a new series of eight parallel lines, started from various tissues of a single spontaneous case, has been carried for six months. On the chance that cells found in a given organ might have a special qualification for the environment of that organ, each line was successively transferred by inoculation with the organ used to start the line. This work is being carried on by Martha J. Taylor. As usual, all lines tend at first to increase in virulence; but differences in the course of this increase appear with a regularity that indicate qualitative differences in different lines. All inoculated mice are being prepared for histological study. So far, two clear-cut physiological differences between two lines have appeared. In the line carried by transfers with the mesenteric node the number of cells in the peripheral blood is regularly several times as high as in any other line. In a line carried by spleen transfers, the late stage of the disease is characterized by extreme anemia.

#### HEREDITARY EYE DEFECTS IN MICE

Two years ago attention was called to the cross between a certain strain of mice with abnormal eyes and normal mice. This cross produced only normals, suggesting that the eye condition was due to a recessive gene. The analysis has now been carried by Laanes into the second back-cross, by which the classification of the animals in the first back-cross is based on the genotype, or germinal condition, rather than the phenotype, or bodily condition. This test shows that the phenotypic normals and abnormals of the first back-cross are genetically very much alike; though back-crosses to abnormal mothers give a somewhat higher percentage of abnormal young. These results agree with the selection results and prove that the genetic control of this defect is complex. Since many eye defects in man, as well



as mice, are genetically complex this strain of mice should prove especially valuable in the analysis of the developmental processes involved and their interaction with environment.

#### GENETICS OF THE THOROUGHBRED HORSE

##### INHERITANCE OF RACING CAPACITY

Laughlin has continued his study of the genetics of the running horse, with the continued support of Mr. W. J. Salmon. He finds that racing capacity does not yield to a simple Mendelian analysis; that there are not merely 1 or 2 genes that determine success in fast running. This is a somatic quality that depends on the complex inter-action of many genes in the course of individual development.

A definite formula has been worked out for the inheritance of racing capacity which gives a close approximation to the facts. This formula is a machine into which we put the measures of racing capacity for each of a number of the antecedent near-kin, direct and collateral, of a potential foal and from which we get out the probability that this particular foal will, if it races, develop a racing capacity within definite capacity-range. This formula is a very complicated one; it will be quite impracticable to reproduce it here.

The elements in the development of this formula may be briefly considered. Given some 54 horses used as a basis for this work, the futurity index of each is computed, and these indices are arranged in ascending order from left to right. Plotted, they constitute the so-called "ogive" curve; for which a close-fitting formula can be found. Next plot against each prediction value the actual racing value (biological handicap) of each of these 54 horses. By joining these latter values there will result a very sharply and deeply serrated line. But its general trend will make an acute angle with the straightened ogive of the futurity indices. Next a straight line is fitted to these biological handicaps, called the biological handicap fluctuation center. From the straightened ogive of hereditary promises (futurity indices) can now be computed the corresponding fluctuation centers. A table is next made of the per cent deviations of each actual racing capacity from its own fluctuation center; and the mean-square deviation computed for the group. By further treatment of these deviations it becomes possible to predict that, with a given futurity index, the racing capacity of the foal will, by a definite probability, deviate not more than a definite per cent from its own computed biological handicap fluctuation center.

##### MATHEMATICAL AIDS TO ANALYSIS OF COMPLEX HEREDITY

Laughlin calls attention to the fact that in Thoroughbred horse breeding only the best are saved for breeding. This means that the futurity index of the foals will be very high. In the 42 racing foals of the Salmon Laboratory farm it is 116.1, on the average, and the range of variability is small. But when the actual racing performance of the 42 is considered, the mean index, or biological handicap, is strikingly lower, *viz*, 97.75, and the variability is high. Just because only a highly selected, narrow upper band of

the "independent variable" is dealt with, some other method than the ordinary correlation method of relating anticipation and performance is called for. Laughlin calls his method that of band correlation, or ogive-regression; and he finds the properties and values of this method extremely useful in the present investigation. By this method one can, for example, through a study of a definite upper stratum of the breeding stock selected on the basis of racing capacity, locate by geometric methods the mean of the breed, although the basic data considered may not have covered this region of racing quality. Band correlation also lays the foundation for building a definite formula for the inheritance of racing capacity in the Thoroughbred horse in the manner accomplished by the present study.

#### GENETIC CONSTITUTION OF THE THOROUGHBRED

The marked discrepancy between the futurity index of an individual and his actual performance has led Laughlin to certain conclusions concerning the "homozygosity" of the Thoroughbred horse. Perhaps no domestic animal is more pure-bred. But within the Thoroughbred breed there are many hereditary differentials—highly significant in racing capacity but relatively insignificant when Thoroughbreds are contrasted with other breeds.

"These differentials are the fine adjustments in heredity. Within this microcosm of fine hereditary differentials all Thoroughbreds are amazingly mongrel in blood. However homogeneous the selected racer may appear, the genotypes are numerous and of varied quality. While mutation must be looked to for radical improvement of the Thoroughbred, there is still much room within every strain of the Thoroughbred to improve greatly by selection among its finely adjusted qualities. For the number of genes involved in racing capacity must be very great."

#### RESULTS OF INBREEDING ON FECUNDITY AND ON GROWTH IN SHEEP

For many years this Department has collaborated with Professor E. G. Ritzman of the New Hampshire Agricultural Experiment Station in a sheep breeding experiment. The attempt to create a new breed by crossing South-down sires and Rambouillet ewes led to repeated inbreeding through three or four generations. The effect of such long inbreeding on size has been recently studied and the study has yielded some interesting and significant results. It appears that the growth of the lambs during the first 4 months in the later generations was slightly greater than in the first hybrid generation—that in which the maximum of growth is ordinarily expected. The adults of the last generation showed exceptionally large males but the average of the 15 ewes was not increased. Also, during the first three generations of inbreeding, fecundity increased slightly. The key to the improvement lay in rigid selection of the best germ-lines for breeding in each successive generation, selection being made on family performance, rather than on somatic condition. However, in the fourth hybrid generation, in consequence of this selective procedure the flock came to be composed almost entirely of one family line. There is only one best; and inbreeding quickly brings that to the front.

## HUMAN GENETICS

## INHERITANCE OF MENTAL ABILITY

The evidence is fairly satisfactory that mental capacity, as measured by school progress, is inherited. To that conclusion the work of Dr. H. J. Banker, as reported in the last few Year Books, has added much critical evidence. This has been possible by his invention of the student's ability index (SAI), and its application to the school records of Huntington village. Banker has now compiled data on the scholastic rank attained by parents and children in particular subjects, especially in spelling and arithmetic. The requirements for comparability set by Banker have been so high that the number of available families is small; is indeed reduced to 14 families with 22 children. The results are given in the tables.

TABLE 2—*Distribution of success in spelling of children from selected matings as measured by the subject SAI in Huntington elementary schools*

Types: L=less than 94; M=94-116 inclusive; H=over 116

Type of parental mating	No. of families	No. of children	Children of each type						Average SAI's	
			Total Nos.			Per cent				
			L	M	H	L	M	H	Mid-parents	Children
L X L										
L X M	5	8	2	3	3	25	37½	37½	93.0	106.9
L X H										
M X M	6	8		4	4		50	50	106.2	113.6
M X H	3	6			6			100	118.4	129.2
H X H										
Totals	14	22	2	7	13	9	32	59	104.1	115.4

TABLE 3—*Distribution of success in arithmetic of children from selected matings as measured by the subject SAI in Huntington elementary schools*

Types: L=less than 94; M=94-116 inclusive; H=over 116

Type of parental mating	No. of families	No. of children	Children of each type						Average SAI'S	
			Total Nos.			Per cent				
			L	M	H	L	M	H	Mid-parents	Children
L X L.....	1	1			1			100	86.0	127.4
L X M.....	6	10	2	8		20	80		94.9	102.8
L X H.....	1	3			3			100	109.5	126.1
M X M.....	5	7		4	3		57	43	101.8	111.1
M X H.....	1	1			1			100	109.8	132.0
H X H.....										
Totals.....	14	22	2	12	8	9	55	36	98.8	110.3

While final conclusions can hardly be drawn from such limited data it does appear that as the special capacity of the mid-parent increases in any subject, that of the average of the children does, in general, increase likewise in the same subject. When the parents are of higher grades in these two subjects the children seem to be more concentrated on high grades, while if the parents are of lower grades, the grades of the children are more dispersed. This suggests, but does not prove, segregation. Peters, also, concluded that there is evidence of Mendelian segregation in special gifts; but his conclusions were based on data less critically gathered, though greater in amount, than those of Banker. This work may be said to add to the cumulative evidence that the mental constitution of the human organism is subject to the same general laws as the strictly physical constitution and is determined in similar degree by genetic factors. Since mentality receives its stimuli and finds its expression through the physical mechanism it is to be expected that it shall be subject to the biological laws of the organism.

#### HEREDITY OF INVENTIVENESS

Inventiveness is one of the most valuable inborn qualities of a race. In extremes a nation calls for some new device or invention that shall save it from destruction. Unhappy that nation whose population can make no adequate response because of lack of capacity for invention. Laughlin has recently, with the assistance of Edith Banta, sought to find out which of the racial elements of our cosmopolitan population shows the greatest proportions of inventors. In this study each of 7373 patentees, out of all the patentees of the first 10,000 patents issued by the United States in 1927, responded to our request for data on his own Old World race-descent. In each case race-stock was computed in terms of eighths; each patentee giving his own descent as accurately as possible by eighths. These eighths were accumulated regardless of combination in individuals. As index of inventiveness for the particular racial stock in the United States was taken the percentage of the patentees represented by the particular race divided by the percentage of the particular racial stock in the whole population of the United States, on the National Origins basis.

This study gave the following indices of inventiveness by race-descent: French 2.92; Swedish 2.45; Dutch 1.97; Danish 1.89; German 1.65; Norwegian 1.60; Swiss 1.41; Irish 1.11; Scottish 1.08; English 1.01; Welsh 0.90; Australian 0.83; Russian, 0.72; Czechoslovakian 0.60; all others 0.45; Italian 0.40; Polish 0.30; Belgian 0.20; Latin American 0.10; and African 0.03.

#### INDIVIDUAL DIFFERENCES IN SENSORY THRESHOLDS

Blakeslee continues, as time permits, his studies on individual differences in reaction to various chemicals that give tastes and odors. When phenylthiocarbamide is placed on the tongue, about a third of the population can detect no taste from the dry crystals; but to most they are bitter in various degrees. But even the "non-tasters" got a reaction from a hot saturated solution. Tests of the least concentrations at which the substance is detected (thresholds) show that in a group of individuals taste acuity for this chemical forms a bimodal curve. From a series of comparable tests with 3



bitter substances, phenylthiocarbamide, quinine sulphate, and picric acid, it was shown that an acute taster for one kind of bitter might be a poor taster for another kind of bitter. It was also shown that there is not a close relation between acuteness of taste for any two of the primary tastes—bitter, sour, sweet and salty.

Very striking is the difference in taste category to which the same substance is assigned by different persons. Thus, some find phenylthiocarbamide sour, others sweet, still others salty. Especially common is the inability to differentiate between bitter and sour. To persons with such inability, the terms bitter and sour may denote a quantitative rather than a qualitative difference. Thus, quinine and hydrochloric acid may both be called sour when diluted and bitter when concentrated.

Blakeslee concludes that probably more or less marked differences in respect to taste thresholds for any sapid substance would be found if a sufficiently large number of individuals were tested. Marked differences in reaction were found to the following dry substances: euquinine, quinine sulphate, benzoate of soda (reported by Dr. A. L. Fox), calcium gluconate (reported by F. Thone), creatine (reported by Roger Williams), fumarprotocetraric acid (reported by A. W. Evans). For some of these substances the tasters and for others the non-tasters were the more common. Apparently there is a greater difference between high and low thresholds for bitter than for sour, sweet or salty substances; consequently bitter will probably be better than other tastes in classifying people as to their taste acuity.

As for taste so also for smell, reactors and non-reactors are found to the same substance. This conclusion is based on tests that have been made with the odors of *Freesias*, *Hemerocallis thunbergii*, *Philadelphus*, a potted *Azalea* and other flowers.

#### THE GENETICAL FACTOR IN OTOSCLEROSIS

By aid of a fund derived from the Carnegie Corporation and coming to us as an appropriation from the Committee on Otosclerosis of the American Otological Society, this Department has been making a study during the past 4 years of heredity of otosclerosis. The first source of our material was the field studies of Dr. Bess Milles, made during 1928 and 1929. Dr. Milles was well trained for this study and had great assistance from Doctors Arthur B. Duel, E. B. Dench, T. J. Harris of New York and Dr. F. E. Shambaugh of Chicago. Additional cases were referred to us by the Volta Bureau.

After Dr. Milles was obliged to relinquish her work, Miss Lillian B. Frink took it up in 1931. She made studies (of members of families that Dr. Milles had begun work upon) in different States of the Mississippi Valley. Later she worked in cooperation with Dr. S. R. Guild at Johns Hopkins Hospital and studied the family history of a number of otosclerotic patients in and about Baltimore.

The results of the field work are found in 60 fairly fully described families. No such carefully and extensively collected data on the distri-



bution of otosclerosis in families has ever been collected in the past; largely because adequate funds had not heretofore been available.

The conclusions from this study have been submitted to the Otological Society for publication. The fact that among otosclerotics over 30 years of age there are nearly twice as many females as males suggested the presence of a sex-linked factor. However, the simplest 10 genetical hypotheses were tested out and the conclusion reached that the hypothesis that otosclerosis is dependent upon two genetical factors, both dominant and one sex-linked, is the most probable. This hypothesis was then applied to the best documented cases and found in no case to be in disaccord with the facts.

#### COMPARATIVE HUMAN AUXOLOGY

The studies in child development during the second decade have been continued, with the cooperation of Letchworth Village. Starting with 120 children, approximately 60 of each sex, semi-annual observations have been made, namely on the birth month and six months later. The observations are morphological, physiological, psychological, roentgenological, hematological. Miss Frink has made studies of the families, in the field; studies that have led her over the state even to Buffalo. About 40 families have been more or less completely studied. For the different members of a single family 30 to 60 or more schedules have been filled out; a single schedule sometimes involving 80 observations.

To make the measurement taken on the two sexes and on persons of different ages more strictly comparable, standards have been sought for each sex and age and the measurements have been expressed as departures from the standards in terms of the standard deviation. While the correlations between parents and young children are not markedly high, still this basis of comparison seems to be the best available. The standard tables and the correlations have been worked out by Mr. William Drager.

The relation between individual and mass studies of child growth has been studied by the Director. The conclusion seems plain that the curve of growth of children based upon mass statistics has little to do with the way the individual child grows. Growth in the second decade shows one or more marked spurts, which may occur at any age from 12 to 17. The form of the mass curve is determined by the relative frequency of occurrence of the abrupt spurts of growth at different ages.

If in the course of the development of different individuals there are marked differences in velocity of growth, it is to be expected that even greater differences will show in the development of those children that belong to different races of mankind. With this hypothesis in mind, Steggerda has begun a series of studies of individual children. It is planned to observe each at yearly intervals until they are grown up. He has measured the same individual Maya Indian children for two successive years; a group of Dutch children living in Holland, Michigan, is being similarly observed; and it is planned to make parallel studies on a group of as nearly full-blooded Negroes as can be found in our Southern States, and on full-blooded Indians of the Southwestern States. Only by such studies can be seen how adult racial differential characters come into being.

## RACIAL PHYSICAL DIFFERENCES BETWEEN INDIANS, NEGROES AND DUTCH

The purpose of anthropometry is to give quantitative expression to the obvious physical differences of the races of mankind. For the most part the data on the physical status of the different races of mankind have been collected by different persons, with more or less differing techniques and usually with very little acquaintance with the history of the individuals they measure and little or no knowledge of their families. In taking up anthropometric work, Steggerda has had the advantage of training in genetics that leads him to make his anthropometric studies on a genetic, familial basis. He has had also the advantage of collecting data himself on the three principal races of mankind—the Negro, the Mongolo-amerindian and the European. During the past year he has completed a study of the Maya Indians of Yucatan, from the physical side. These Indians have an exceptionally short stature, very short as compared with Negroes of Jamaica and the Dutch. The relative span of the Indian, although not so great as that of the Negro, is still significantly greater than that of the Whites. The relative chest girth of the Mayas is astonishingly great, being about 57 per cent of stature, while in the Negroes this ratio is about 50 per cent and in the Dutch about 54 per cent.

The Indian has also a relatively long trunk and short legs. Thus his relative sitting height is 53 per cent as compared with 51.5 per cent in the case of the Negroes. The Maya Indian has broad shoulders, his shoulder breadth equalling those of the Plains Indians, who are considerably taller. Other striking traits of the Maya Indians as contrasted with Negroes are: broader pelvis; shorter arms, but relatively longer distal segment of the arm; broader, shorter head; broader face; narrower nose; longer, narrower ears; and more resistant teeth. Three of the average measurements differed somewhat from those obtained by G. D. Williams, who also measured the Mayas. These differences are attributed to slight differences in technique; and to the probability of more white blood in the Mayas measured by Williams.

## MUTATION AMONG AMERICAN INDIANS

The American Indian is far from being a morphologically single homogeneous race; on the contrary, in the course of the post-glacial period during which it has occupied this continent, it has undergone a great number of mutations. Steggerda has plotted the distribution of some of these. Starting from the Great Plateau region, the Indians fall off in stature as one goes southward and increase in stature as one goes eastward. A stream of brachycephalism extends from Alaska to Panama. In the northeastern part of the continent the skulls become more dolichocephalic.

## METABOLISM AMONG THE MAYAS

After having measured basal metabolism among the Negroes of Jamaica, Steggerda was especially qualified to cooperate with Dr. F. C. Benedict of the Nutrition Laboratory in measuring the metabolism of the Mayas. This he did and found it to be 8 per cent higher than the norms of Whites, while the pulse rate, taken in a state of complete repose, was found to be on the average 52 per minute, or 9 less than the average for Whites. There seems to be little doubt, consequently, that the races of mankind show differences in basal metabolism, as Benedict concludes. Riddle has argued that the

high basal metabolism of the Maya may be due to the slight amount of clothing worn by them even in cold weather. And it is true that the Maya Indians, in general, sleep in hammocks, covered only by the scant cotton clothing they wear during the heat of the day, though the temperature may fall, during the winter months, to 5° C. above zero. However, some of the basal metabolisms taken by Williams were made in May, when the weather is warm even at night; and such also show the high rate.

#### FOOD OF THE MAYA INDIANS

As an investigation supplementary to that on basal metabolism, Steggerda undertook to secure for Dr. Benedict samples of food used by the Maya Indians. About 65 food samples were gathered and preserved and, in addition, a like sample of the food eaten by four Maya men for three successive days was preserved and sent on to Boston for analysis.

#### FAMILY ANALYSIS

While the Eugenics Record Office has records of about 25,000 families each systematically described by some member of the family, the average number of persons adequately described in each is small, probably not averaging over 17 persons. Steggerda has recently presented to the Office certain manuscript records of the Steggerda family and the families with which it has intermarried. In the entire study there are involved 963 individuals, of whom about one-quarter have been studied anthropometrically, each yielding from 25 to 50 physical measurements. The work has been done intermittently during the past 10 years. Two studies have been recently published, made on this material. In the first, the data include the birth weights of 48 individuals, and the high sex ratio of 110, based on 432 individuals. Familial causes of death are tuberculosis and cancer. Differing traits of personality characterize different lines; but in each line there is a strikingly high proportion of one trait, such as humor, generosity, craftsmanship.

The second completed study is called, "Physical Measurements in Dutch Men and Women." The results have been discussed above in considering the Maya Indian material.

#### RACE DIFFERENCES IN HANDS AND FINGERS

From a comparative study of the hands of Dutch, Negroes and Maya Indians, Steggerda finds them largest in the Whites; and smallest in the Mayas. But the Indians have the relatively broadest and shortest hands; while those of the Negroes are shortest. From a study of each individual finger the conclusion is drawn that the fingers are more nearly alike in the two sexes in the Negroes than in the other two groups. Also the difference in length between digits IV and II is greatest in the Indians; between III and II is least in the Whites and between III and IV is least in the Indians.

#### GENETIC CONSTITUTION OF AMERICAN POPULATION

##### EUGENICAL STERILIZATION

The Eugenics Record continues to be called upon for advice on the legislative, judicial and administrative aspects of eugenical sterilization. This makes it necessary to keep in touch with the working out of sterilization



laws. Laughlin finds that up to December 1, 1931, a total of 15,151 persons have been sterilized in 30 different states under the eugenical statutes since their beginning in 1907. Twenty-seven states still have eugenical sterilization laws. Currently, the laws which are being tested by the courts are being quite uniformly upheld as constitutional, in contrast with earlier findings. This change has been due largely to the elimination of the therapeutic and punitive factors in the statutes, so that the state's motive in its enactment becomes emphasized as purely eugenical.

Laughlin finds that the standards for sterilization are so conservative that there has been no complaint that any state has lost valuable breeding stock. Meanwhile, the states are gaining valuable experience in eugenical sterilization—the legislators in defining the legal standards of hereditary degeneracy, the administrative officers in nominating persons for sterilization and in preparing cases for presentation to the courts and, finally, the courts in judging the biological evidence of hereditary degeneracy. There has been a steady growth of the biological motive in legislation, in court decisions and in the administration of these statutes. Also the compulsory feature is now soundly established in legislation and in long practice. Progress in this field demands further research in human heredity.

#### RACIAL ASPECTS OF CRIME IN THE UNITED STATES

Ten years ago Laughlin prepared for the Congressional Committee on Immigration a statistical statement as to the proportional amount of crime in the racial stocks represented in the United States. During the past year he has made a similar study of the prisoners as of October 1, 1931. It was expected that the study would determine whether certain features of the Immigration Control Act of 1924 designed to reduce alien crime in the United States were successful. The method of race-quota fulfillment was used. Some of the findings are: Ten years ago the quota fulfillment for crime by all foreign-born was 109.91; in 1931 it was found to be 70.83, a very substantial reduction. Immigrants from Northwestern Europe reduced their quota fulfillment from 53.32 to 41.14. Italians cut their crime rate from 209.72 to 111.23. Native-born whites, only one parent foreign born, cut the rate from 113.67 to 73.75. Native-born whites, both parents foreign born, from 86.21 to 80.71. The Filipinos, not measured in 1921, gave a crime quota of 230.43. All colored races show very high crime rates. The reduction of the felony rate during ten years to one-third seems to be due to the restrictive measures of the Congressional Acts of 1921 and 1924, to the overseas examinations and to increased deportation. Laughlin draws the conclusion that, under modern conditions, immigration control is that feature of legislation that leads to greatest results in the field of applied eugenics.





# GEOPHYSICAL LABORATORY<sup>1</sup>

ARTHUR L. DAY, DIRECTOR

## THE ELASTICITY OF ROCKS<sup>2</sup>

Less than ten years ago it became practicable for the first time to measure directly the cubic compressibility of rocks. The measurements, which were made at this Laboratory (see Publication No. 484) by the use of high hydrostatic pressures, enabled us to know something of the true elasticity of typical rocks under conditions comparable with those existing within the crust of the Earth. Previously, indirect methods of several kinds had yielded some information concerning the elastic properties of rocks, but the results were not entirely conclusive and were not immediately applicable to natural rock formations, which, except at the surface, are subjected to very considerable pressures.

Our measurements have made it possible to calculate the velocity with which longitudinal vibrations are transmitted through various types of rocks at different pressures. The value obtained for granite at a pressure corresponding to a depth of about 10 km. was 5.6 km./sec., and it was gratifying to find that this is precisely the value announced by seismologists as the measured velocity of longitudinal vibrations in the uppermost, presumably granitic, layer of the Earth. This agreement justified the expectation that laboratory measurements could be used to calculate earthquake-wave velocities in typical rocks and measured earthquake-wave velocities might thus afford a clue to the type of rock at different depths through which the elastic waves may have passed.

The determination of the elasticity of solids by any method is not an easy task; it is required to measure with acceptable precision the variation in some property which usually changes by only one or two parts per million for each atmosphere increase in pressure. High hydrostatic pressure here affords us an immense advantage. The volume changes, which are so small when only one atmosphere is available, can here be multiplied 10,000 times, and, in addition, we can avoid, or compensate for, the irregularities and disturbances which appear at very low pressures, especially with coarsely crystalline materials.

Methods, which, although indirect, make use of hydrostatic pressure, have in some instances given reliable results for the cubic compressibilities of *homogeneous* materials. Indeed the linear compression method developed by Bridgman is capable of higher precision than any direct method hitherto available, but curious anomalies observed with certain materials seem to indicate that the linear method can be trusted implicitly only for specimens cut either from a single crystal, or from a malleable material such as a metal, even though independent sets of measurements on separate pieces cut to three different axes may be made.

The direct method gives results for the cubic compressibility that are accurate to about 1 per cent, provided the material is homogeneous, or

<sup>1</sup> Situated in Washington, District of Columbia.

<sup>2</sup> Adams, Gibson, Goranson.

rather, the mean value of the compressibility over the experimental pressure range is determined with this accuracy, which corresponds to an accuracy of 0.5 per cent in the wave velocity. If the material, like most rocks, either is inhomogeneous (*i.e.* is a crystalline aggregate), or is somewhat porous, or it has a compressibility that changes considerably with pressure, then the possible accuracy in the determination of compressibility at any given pressure is much less than in the most favorable case, but probably is sufficient to allow the wave velocity to be calculated within 2 or 3 per cent.

A survey of all the existing measurements of compressibility hitherto made on rocks indicates that in order to obtain trustworthy values it is certainly necessary to use hydrostatic pressure, to measure *volume* changes, to make the measurements over a large range of pressures (preferably at least 10,000 atmospheres), and, unless the porosity is very low, to enclose the specimen in a jacket impervious to the pressure fluid, so that the closing in of pore spaces may have an opportunity to contribute its share to the volume change. Unless these conditions are met, the results are likely to be of inferior accuracy, incomplete, or not representative of actual pressure conditions within the Earth.

#### LIMITATIONS

Although important progress has been made, there are serious limitations to our knowledge of this subject. Little is known concerning the effect of temperature on the elasticity of solids and practically nothing at all concerning this temperature coefficient for rocks. The effect is not large for those solids which have been investigated and presumably it is still smaller at high pressures than at atmospheric pressure, but measurements of compressibility at temperatures up to 1000° are much needed.

For rocks, one of the most obvious deficiencies in compressibility measurements lies in the low-pressure region. There are no direct measurements of the cubic compressibility of any rock available at pressures below 1000 atmospheres. High-pressure apparatus is not suitable for measurements at these low pressures. For such measurements to be of value, somewhat higher accuracy than that obtained heretofore is required and probably a different type of apparatus will be needed. The measurements on rocks by F. D. Adams and E. G. Coker, using an indirect method, pertain to an effective pressure of only a few hundred atmospheres, and the results for many of the materials investigated by them are consistent with the high-pressure results for the same materials and indicate that this indirect method yields reliable determinations for substances that are homogeneous or fine-grained. On the other hand, the recent field measurements by Leet and Ewing on the velocity of elastic waves through granitic rocks indicate that the compressibility of granite at low pressures (20 or 30 atmospheres) is much lower than the value obtained by the indirect method and may possibly also indicate that no indirect method will give correct results for coarse-grained porous materials.

The relation between rigidity and compressibility is known approximately and has been used to estimate the rigidity from known values of the bulk modulus or compressibility, but it would, of course, be very

desirable to measure directly the rigidities of typical rocks at various pressures. Another factor that might properly receive more attention is hysteresis. Although it is impossible for the volume change of a homogeneous material to show any hysteresis under hydrostatic pressure, such an effect might conceivably exist for a rock consisting of an assemblage of different minerals. What few measurements we have fail to show any indication of this effect, but the subject is in need of further investigation.

#### RÉSUMÉ OF PRESENT RESULTS

Although little is yet known concerning the elastic properties of rocks at high temperatures or at low pressures we have, at high pressures and room temperature, a fairly satisfactory picture of the compressibilities of typical igneous rocks, and a somewhat less adequate notion of their rigidities. The compressibilities cover a wide range of values (from about that of steel in the case of peridotite and eclogite types to nearly five times that of steel in the case of highly siliceous rocks), but except at the lower pressures the compressibility of a given rock is the mean of the compressibilities of the constituent minerals and is thus directly related to the chemical composition. This part of the problem appears, therefore, to have been solved. The results are sufficiently complete and reliable to justify their application to various phases of geophysics, and, especially in conjunction with seismologic data, to give us very definite information concerning the interior of the Earth; but the deficiencies in the domains of low pressure and high temperature have been the cause of some doubt and misapprehension as to the validity and applicability of the results. It is an altogether unfortunate circumstance that so few investigators have had the facilities and the opportunity for making measurements on the fundamental mechanical properties of the constituents of the Earth's crust. The data already obtained would perhaps acquire increased value through a wide extension in the range and variety of the measurements.

#### FERROUS SILICATES AND THE SYSTEM, $\text{CaO-FeO-SiO}_2$ <sup>1</sup>

Of the various oxides that enter into the constitution of the accessible part of the earth, the iron oxides rank third in order of abundance, being exceeded only by silica and alumina.

The oxides exist, for the most part, in the form of compounds with silica, giving rise to the mineral compounds known as silicates and, of all silicates, the aluminosilicates known as the feldspars are unquestionably the most important. It was for this reason that upon the organization of the Geophysical Laboratory the first mineral series investigated was the feldspar series.

Probably second in order of importance among rock-forming mineral groups is the group known as the pyroxenes and to these attention was next directed. The pyroxenes are a very complex group into whose constitution may enter a great number of the rock-forming oxides, but they are commonly metasilicates of lime, magnesia and iron. The pure or nearly pure metasilicate of lime occurs in rocks as the mineral wollastonite,  $\text{CaSiO}_3$ , and, following the plan ordinarily adhered to in the Geophysical

<sup>1</sup> Bowen, Schairer.



Laboratory of proceeding from the simple to the more complex, the simple pyroxene-forming compound,  $\text{CaSiO}_3$ , was the next silicate compound whose thermal behavior was made the subject of investigation. The corresponding magnesian silicate,  $\text{MgSiO}_3$ , was next examined and then the relation between these two silicates. It was found that they formed the simple ternary compound  $\text{CaSiO}_3 \cdot \text{MgSiO}_3$  or, as it may be written,  $\text{CaMgSi}_2\text{O}_6$ . This ternary compound occurs in nature as the mineral diopside, and its thermal relations, or more specifically its equilibrium with liquids (melts) and with the two constituent compounds  $\text{CaSiO}_3$  and  $\text{MgSiO}_3$ , was found susceptible of complete elucidation by laboratory methods.

A long step was thus made towards an understanding of the pyroxene group of minerals, the molecules  $\text{CaSiO}_3$  and  $\text{MgSiO}_3$  and especially the more complex diopside molecule,  $\text{CaMgSi}_2\text{O}_6$ , being on the whole the most important molecules entering into the constitution of the pyroxenes. However, a good deal still remained to be learned, for the rock-forming pyroxenes typically contain much iron oxide in addition to lime and magnesia. Accordingly many attempts have been made, in the period that has elapsed since the above-mentioned studies were carried out, to solve the problem of the relation between the iron oxides (particularly ferrous oxide) and silica, with the particular object of ascertaining the manner in which ferrous oxide ( $\text{FeO}$ ) enters into the constitution of the pyroxenes and the effect of its presence upon equilibrium relations.

It was known from analyses of natural pyroxenes that a compound analogous to diopside ( $\text{CaMgSi}_2\text{O}_6$ ), but having ferrous oxide instead of magnesia, is an important constituent of pyroxene. This compound is  $\text{CaFeSi}_2\text{O}_6$ , which sometimes occurs independently as the mineral, hedenbergite, and efforts were directed particularly towards a solution of the equilibrium relations of diopside and hedenbergite. Although a few isolated facts were ascertained, little of systematic value was brought to light by these efforts and nothing on the subject has appeared in the published records of the researches of the Geophysical Laboratory.

The difficulty involved in the work was the practical one of controlling and defining the state of oxidation of the iron and particularly of keeping all or nearly all the iron in the ferrous state. Renewed efforts to solve this problem have recently been made and finally a method has been found for treating silicate systems of which ferrous oxide is one of the components and of carrying out the treatment under completely controlled and measured conditions. These efforts were again directed particularly towards a solution of the hedenbergite problem and as the work progressed it was soon found that the thermal behavior of hedenbergite is so complex that for a complete understanding of its relations it was necessary to work out the system,  $\text{CaO-FeO-SiO}_2$ .

It so happens that this system is also of fundamental importance to metallurgy, since all slags, except iron blast-furnace slags, are made up, at least principally and sometimes almost exclusively, of the above ingredients. So important is it that, not long ago, a metallurgical authority wrote: "If pressure could be brought to bear on the Geophysical Laboratory perhaps they would work out the system  $\text{FeO-CaO-SiO}_2$  the way they

have done the lime, magnesia, alumina, silica systems and then we should have a sound basis from which to begin our work on slags containing iron oxide." From what has been said above of the importance of the system to an understanding of the great group of rock-forming minerals, the pyroxenes, and of the efforts that have been made to solve the problems of this group, it will be plain that no external "pressure" has been necessary. But if the results are found to be as important to the problems of the metallurgist as they are to the problems of the petrologist, their accomplishment will be doubly gratifying.

The method of procedure which proved to be wholly satisfactory for thermal studies of silicates containing ferrous iron is comparatively simple in principle. It consists in substituting for the chemically inactive platinum crucible ordinarily used in silicate studies a crucible of pure (electrolytic) iron and of conducting the operations in an atmosphere of nitrogen. Such further modification of the ordinary procedure as is necessary in matters of detail need not be discussed here.

Before giving an outline of the systematic results and describing the equilibrium diagram of the system,  $\text{CaO-FeO-SiO}_2$ , it is necessary to point out one outstanding feature of iron-silicate liquids; metallic iron is incapable of reducing all of the iron oxide of such liquids to the ferrous state. When equilibrium is established with the iron crucible there is still a small percentage of the iron in the ferric state as shown by chemical analyses of the "quenched" liquid. That this is a true equilibrium and not the result of any lag effect is shown by the fact that equilibrium can be approached from the opposite direction with like result. Thus, if a *crystalline* ferrous silicate (*e.g.*, fayalite) is melted it does so with the separation of a little metallic iron, and the liquid, which must be complementary in composition, necessarily contains a little of its iron in the ferric state. *There is thus no possibility of obtaining silicate liquids bearing iron oxide in which all of the iron oxide is in the ferrous state.* When the ferric oxide is reduced to a certain small value the liquid is then in equilibrium with metallic iron and further attempts at reduction, even with a powerful reducing agent, will result only in the separation of metallic iron without change in the ferric-oxide content of the liquid.

The actual amount of ferric oxide in the liquid in equilibrium with solid iron and with a solid ferrous-silicate phase has been determined for a wide range of liquids in the system,  $\text{CaO-FeO-SiO}_2$ , or, more accurately speaking, in a portion of the system,  $\text{CaO-FeO-Fe}_2\text{O}_3\text{-SiO}_2$ . The quantity of  $\text{Fe}_2\text{O}_3$  is always small (about 2 per cent at orthosilicate compositions and 1 per cent at metasilicate compositions). On account of the difficulty of presenting four component equilibrium graphically, it is desirable to neglect these small amounts of  $\text{Fe}_2\text{O}_3$  in the liquid, to calculate all iron oxide as  $\text{FeO}$  and present the results in the form of a ternary diagram (see accompanying figures).

The diagram shows that in the limiting "binary" system,  $\text{FeO-SiO}_2$ , there is only the one compound  $\text{Fe}_2\text{SiO}_4$  (fayalite) which melts at  $1205^\circ\text{C}$ . No compound of the composition  $\text{FeSiO}_3$  appears on the liquidus nor can such a compound be induced to form even at temperatures as low as  $660^\circ$ .



Another "binary" system requiring special mention is the system,  $\text{Ca}_2\text{SiO}_4\text{--Fe}_2\text{SiO}_4$ . Here there is an intermediate compound,  $\text{CaFeSiO}_4$ , which melts at  $1208^\circ$ . With fayalite ( $\text{Fe}_2\text{SiO}_4$ ) this compound forms a complete series of solid solutions (lime-iron olivines) of the type with a minimum (Type III Roozeboom) and with  $\text{Ca}_2\text{SiO}_4$  a broken series of solid solutions (Type IV Roozeboom).

There is one other "binary" system, the system,  $\text{CaSiO}_3\text{--CaFeSiO}_4$ , which is of the simple eutectic type.

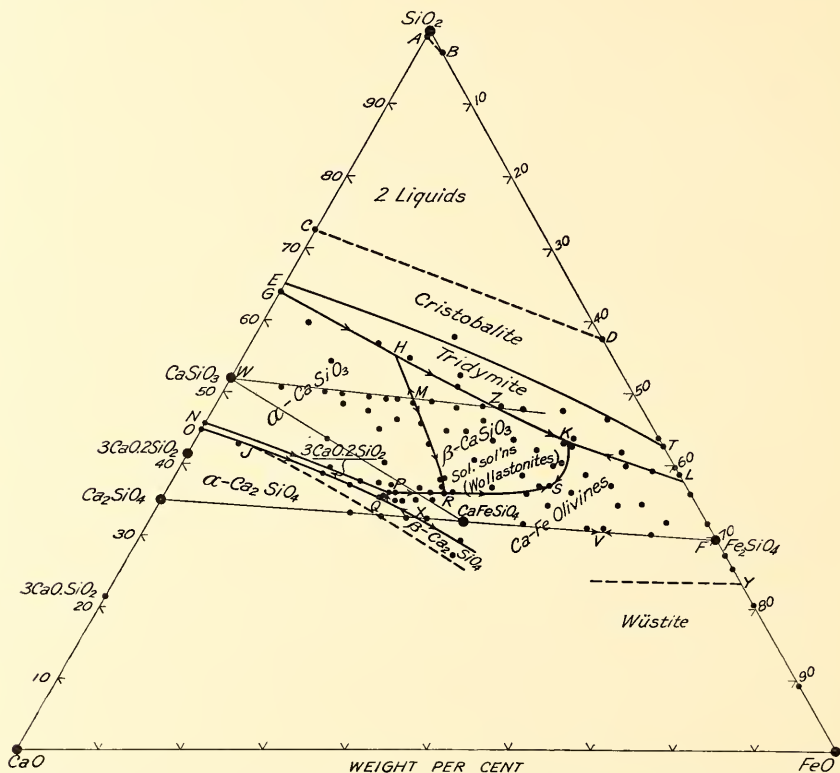


FIG. 1—Equilibrium diagram of the system  $\text{CaO--FeO--SiO}_2$  showing fields of stability of various crystalline phases in contact with liquid. Small solid circles indicate determined points.

Aside from these simple systems, the relations within the ternary system are exceedingly complex, the complexity being due to the wide prevalence of solid solutions and of the phenomenon of incongruent melting. Little was done with mixtures lower in  $\text{SiO}_2$  than the orthosilicate ratio because they have little if any petrologic importance.

The compound  $\text{CaSiO}_3$  in the  $\alpha$ -form takes no iron into solid solution but in the  $\beta$ -form (wollastonite) a series of solid solutions extends over towards " $\text{FeSiO}_3$ " as far as 75 per cent of that compound, although that compound itself has no existence as a separate crystalline phase. We thus get wollastonites with more than three times as much  $\text{FeO}$  as  $\text{CaO}$ .

The equilibrium between these metasilicate solid solutions and the orthosilicate solid solutions (olivines) has been worked out in full detail. There is no ternary eutectic in that portion of the system completely covered by the investigation. The lowest point is a minimum (1093°) on the boundary curve between the fields of lime-iron olivines and wollastonite solid solutions. Here only these two solid phases (solid solutions) are in equilibrium with liquid, whereas a eutectic requires, of course, three solid phases. There are several quintuple points where three solid phases are in equilib-

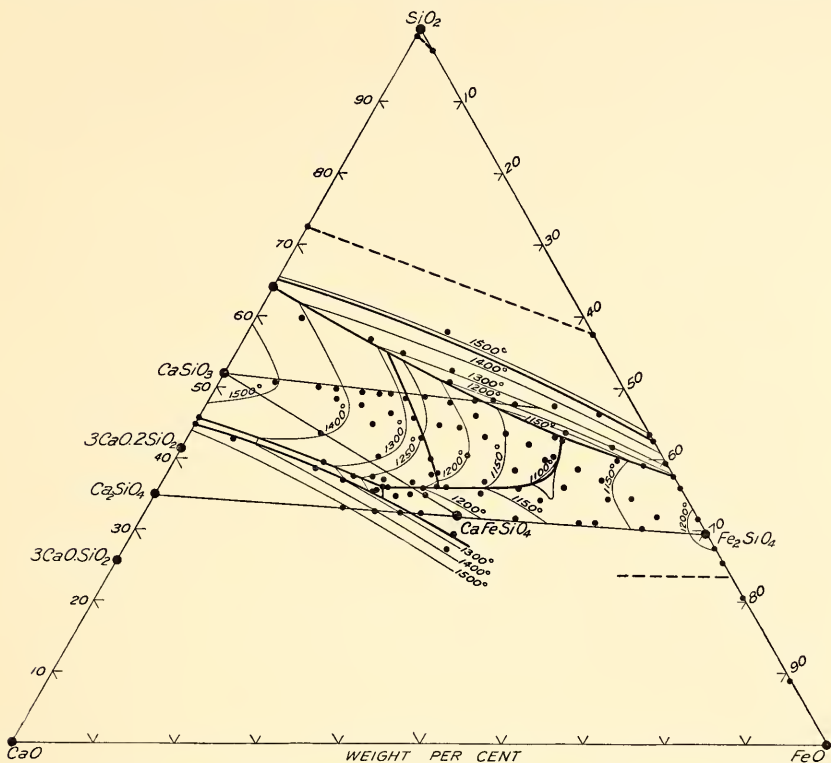


FIG. 2.—Same as figure 1 with isotherms showing temperature of completion of melting (or beginning of crystallization) of all mixtures in area investigated.

rium with liquid (and vapor) but all are of the reaction type, none are eutectic.

The compound  $\text{CaFeSi}_2\text{O}_6$  (hedenbergite), which is the compound of greatest interest in connection with rock-forming pyroxenes, does not form at any temperature at which liquid occurs in the system. It therefore required a great deal of work with solid materials at low temperatures to determine the equilibrium relations of the compound. Hedenbergite is stable only up to 965° at which temperature it inverts to material of its own composition, but this material is no longer a compound. It is merely one of the wollastonite solid solutions, in no respect a unique point in that series. This inversion product begins to melt about 1020° but its melting

is incongruent, taking place with separation of  $\text{SiO}_2$  (tridymite). The equilibrium in this temperature range can therefore be represented only in terms of a ternary system. With rise of temperature the amount of tridymite increases, passes through a maximum and then diminishes until at  $1060^\circ$  tridymite has disappeared and the equilibrium again becomes binary, the material then consisting of liquid and one solid which is one of the wollastonite solid solutions, rich in lime. Further rise of temperature brings about solution of the solid phase in the liquid and an increase of the lime content of the solid phase until at  $1202^\circ$  the mass is entirely liquid. The thermal behavior of material of the composition  $\text{CaFeSi}_2\text{O}_6$  is thus of a very complex character. Additional complication is introduced by the fact that hedenbergite takes " $\text{FeSiO}_3$ " into solid solution and there are thus two metasilicate series of solid solutions, the hedenbergite series, stable at lower temperatures, and the wollastonite series, stable at higher temperatures.

With a method of treating melts containing ferrous iron developed and with the relations of hedenbergite fully solved, it is now a straightforward matter to investigate mixtures of hedenbergite with other pyroxene molecules and thus to gain a fuller understanding of relations within the pyroxene group.

## PUBLICATIONS

- (768) Gradual transition in sodium nitrate. II. The structure at various temperatures and its bearing on molecular rotation. F. C. Kracek, E. Posnjak, and S. B. Hendricks. *J. Am. Chem. Soc.* 53, 3339-3348. 1931.

The gradual transition in sodium nitrate (cf. Laboratory Publication No. 759, Annual Report for 1931) has been further investigated by analysis of the crystal structure at various temperatures. It was found that the symmetry of the crystal remains trigonal throughout; the dimensions of the unit cell are characterized by  $a_0 = 6.32 \text{ \AA}$ ,  $\alpha = 47^\circ 14'$  at  $25^\circ \text{C}$ ., and  $a_0 = 6.56 \text{ \AA}$ ,  $\alpha = 45^\circ 35'$  at  $280^\circ \text{C}$ ., with  $2\text{NaNO}_3$  in the unit of structure. The net increase in volume during the anomalous expansion preceding the transition is produced by an abnormal increase of  $a_0$  accompanied by a gradual decrease in  $\alpha$ ; hence the anomalous expansion is principally along the  $c$  axis of the crystal. The intensities of diffraction of X-rays from planes in which oxygens alone contribute to the reflections are strong and normal to about  $200^\circ$ , but decrease rapidly toward zero as the temperature is increased to  $280^\circ$ . This indicates that from about  $200^\circ$  the oxygen atoms gradually cease to occupy discrete fixed positions and leads to the interpretation that as the temperature increases above  $200^\circ$  the nitrate groups in the crystal are undergoing oscillations of gradually increasing amplitude about their equilibrium positions until at  $275^\circ$  they are free to rotate about the trigonal ( $c$ ) axis of the crystal.

- (769) Group rotation in solid ammonium and calcium nitrates. F. C. Kracek, S. B. Hendricks and E. Posnjak. *Nature* 128, 410-411. 1931.

Ammonium nitrate at atmospheric pressure is known to exist in at least five crystalline modifications, with the inversion points at  $-18^\circ$ ,  $+32^\circ$ ,  $84^\circ$ , and  $125^\circ \text{C}$ . In addition to these polymorphic transitions there is a gradual transition at about  $-50^\circ \text{C}$ . The ammonium ion is probably free to rotate at all temperatures above  $-50^\circ \text{C}$ . The nitrate ion is free to rotate about three orthogonal axes in the high temperature modification which is cubic,

$a_0 = 4.40 \text{ \AA}$  at  $155^\circ\text{C.}$ , with  $1\text{NH}_4\text{NO}_3$  in the unit of structure. The rotation in this case is initiated at a polymorphic transition. The tetragonal modification ( $84^\circ$  to  $125^\circ$ ) has  $a_0 = 5.77 \text{ \AA}$ ,  $c_0 = 5.00 \text{ \AA}$ , and  $2\text{NH}_4\text{NO}_3$  in the unit of structure. The nitrate ions may be free to rotate about axes normal to their planes. The nitrate ions in the cubic calcium nitrate (anhydrous) rotate with spherical symmetry, the  $\text{Ca}^{++}$  to  $\text{NO}_3^-$  distance being  $3.30 \text{ \AA}$ .

(770) The compressibility of fayalite, and the velocity of elastic waves in peridotite with different iron-magnesium ratios. L. H. Adams. Gerlands Beiträge zur Geophysik 31, 315-321. 1931.

Some time ago it was found possible for the first time to obtain satisfactory measurements on the cubic compressibility of typical igneous rocks at high pressures, and thence to calculate the velocity of longitudinal and of transverse vibrations through such materials (see Laboratory Publication No. 484). These results have now been made more complete by a determination of the influence of varying amounts of iron oxide and magnesia on the compressibility of peridotite rocks. Measurements were made on the effect of pressure on the volume of (1) a rock consisting of olivine that contained 7 per cent FeO and (2) pure fayalite ( $\text{Fe}_2\text{SiO}_4$ ). From these measurements the compressibility of pure forsterite was found to be  $0.82 \times 10^{-6}$  and  $0.73 \times 10^{-6}$  per bar respectively at atmospheric pressure and at 15,000 bars. The latter pressure is equivalent to a depth of about 50 km. below the surface of the Earth. For fayalite the compressibility is notably higher, namely,  $0.96 \times 10^{-6}$  and  $0.84 \times 10^{-6}$  at the corresponding pressures. The velocity of longitudinal waves in rocks varying in composition between pure forsterite and pure fayalite would, therefore, range between 8.6 and 7.1 km./sec. at a pressure of 15,000 bars. On the reasonable assumption that in peridotite within the Earth the molecular ratio of MgO to FeO is about 4 to 1, the velocity of longitudinal waves in this peridotite would be 8.2 km./sec. at a depth of 50 km. (disregarding the unknown effect of temperature).

This result may be compared with the results of the previous measurements on pyroxenes which showed that in the enstatite-pyroxene series the variation of velocity with iron-content is very small and that the velocity of longitudinal waves at 15,000 bars in a hypersthene rock is 7.4 km./sec.

(771) Silicate structures of the cristobalite type. I. The crystal structure of  $\alpha$ -carnegieite ( $\text{NaAlSiO}_4$ ). Tom. F. W. Barth and E. Posnjak. Z. Krist. 81, 135-141. 1932.

This is the first of a series of three papers on structures of this type, and is reviewed with the other two under Laboratory Publication No. 779.

(772) The cubic compressibility of certain substances. L. H. Adams and R. E. Gibson. J. Wash. Acad. Sci. 21, 381-390. 1931.

In this paper are presented the results on the cubic compressibility of a number of materials. The compressibilities were determined at pressures ranging from 1 to 12,000 bars by the usual piston-displacement method. Results are given for Pyrex glass, vitreous silica, obsidian, duralumin, ammonium nitrate, potassium sulfate, sodium sulfate, and n-butyl ether. The measurements illustrate the variety of ways in which the compressibility of matter changes with pressure. At one extreme are the silica-rich glasses, the compressibility of which *increases* noticeably at higher pressures; at the other, are liquids such as butyl ether, the compressibility of which *decreases* very rapidly up to 5 kilobars while at higher pressures its compressibility changes not more than that of a solid like ammonium nitrate.



- (773) A new type of crystal fine-structure: Lithium ferrite ( $\text{Li}_2\text{O} \cdot \text{Fe}_2\text{O}_3$ ). E. Posnjak and Tom. F. W. Barth. *Phys. Rev.* 38, 2234-2239. 1931.

The interpretation of the X-ray diffraction obtained from the isometric modification of lithium ferrite resulted in the conclusion that the smallest "unit" of this structure contains four anions and four cations. The anions, oxygens, occupy the four equivalent points 4b while the cations, iron and lithium, occupy together the four equivalent points 4c. The large difference in the scattering power of iron and lithium makes it possible to arrive at the definite conclusion that in the structure of lithium ferrite the same set of equivalent positions is occupied by the two chemically different elements (variate atom equipoints). It is shown that the distribution of iron and lithium in this set of equipoints is not regular; that is, there are not always two of each cation present in the "unit"; the distribution is one of chance, which, however, must comply with the requirement that an equal number of each of the cations is always present within a relatively small space. In view of these findings the conception of the unit cell loses its traditional chemical significance and becomes strictly a geometric conception. The "unit cell" of lithium ferrite has a meaning only if its lattice be regarded as geometric points in space. The lattice of lithium ferrite is then identical with the one of the "sodium chloride" structure (4b, 4c); the unit cube contains one molecule of  $\text{Li}_2\text{O} \cdot \text{Fe}_2\text{O}_3$ , and the length of its edge is  $4.141 \pm 0.005 \text{ \AA}$ . The density of lithium ferrite is 4.368 and its refractive index  $n_{\text{Li}} = 2.40 \pm 0.04$ .

- (774) The stability relations of goethite and hematite. A reply to Dr. J. W. Gruner. G. Tunell and E. Posnjak. *Econ. Geol.* 26, 894-898. 1931.

Experiments carried out by Gruner since the publication of "The stability relations of goethite and hematite" by Tunell and Posnjak, disprove Gruner's earlier conclusion as to the temperature of the invariant point,  $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$  (goethite),  $\text{Fe}_2\text{O}_3$  (hematite), solution, vapor, in the system,  $\text{Fe}_2\text{O}_3$ - $\text{H}_2\text{O}$ , and bring him nearly into agreement with Posnjak and Merwin.

- (775) The minerals of Connecticut. J. F. Schairer. *Conn. State Geol. and Nat. Hist. Surv. Bull.* No. 51, 121 pp., 1931. (Price, \$0.75.)

This bulletin describes the general physical and chemical properties of minerals and discusses the modes of origin of rocks and ore deposits. A detailed description of one hundred of the common minerals found in Connecticut is given. The principal mineral localities of Connecticut are described in detail. The bulletin is intended for use by teachers, naturalists, land-owners, miners, quarrymen, etc., who wish to study the minerals and rocks which are so well exposed everywhere in the State. An effort has been made to present the fundamental concepts, and by means of footnote references and a bibliography the reader is introduced to the more advanced and technical aspects of mineralogy and petrology.

- (776) Permanent changes in the optical orientation of feldspars exposed to heat. Tom. F. W. Barth. *Norsk Geol. Tidsskrift* 12, 57-72. 1931.

It is an interesting circumstance that the optical properties of many feldspars when heated will undergo irreversible changes.

New data on this effect for various kinds of feldspar are given.

*Orthoclase* frequently exhibits conspicuously large changes of the optic axial angle whereas the position of the optical indicatrix remains unchanged. It was found to be a general rule that the more potassic the feldspar the greater the change.



*Microcline* is *not* changed by heat treatment. Since it has been claimed that microcline, if heated long enough, will slowly invert to orthoclase, it is worthy of notice that this statement is proved to be false.

*Albite* and *oligoclase* are very slightly changed on heating.

*Labradorite* exhibits appreciable alterations of both the position and shape of the optical indicatrix.

- (777) Equilibrium in binary systems under pressure. II. The system,  $K_2SO_4-H_2O$ , at  $25^\circ$ .  
L. H. Adams. J. Am. Chem. Soc. 54, 2229-2243. 1932.

In accordance with the experimental and calculatory methods described in the first paper of this series (Laboratory Publication No. 767) the system,  $K_2SO_4-H_2O$ , has now been investigated at pressures up to approximately 10,000 bars and at  $25^\circ$ . From the measurements of the compressions (relative volume changes) of aqueous solutions of potassium sulfate and of the solid salt, the fictive volumes, chemical potentials, and conditions of stability in the system have been determined.

Under pressure the fictive volume of the salt shows the same striking *increase* that was observed previously for sodium chloride. This phenomenon suggests that pressure causes solutions to become more nearly ideal. The equilibrium diagram for this system has the same general appearance as for the system,  $NaCl-H_2O$ , but the diagram is more simple in form and the variation in solubility is much greater than with  $NaCl$ .

The indirectly determined equilibrium diagram was confirmed by direct measurements of the eutectic pressure and the freezing pressure of a 10 per cent solution.

- (778) Temperature of formation of the ilmenite of the Engels copper deposits—A discussion. With appendix. J. W. Greig. Econ. Geol. 27, 25-38. 1932.

This paper is a discussion of the argument used by Knopf and Anderson (The Engels copper deposits, California, Econ. Geol. 25, 14-35, 1930) to fix a lower limit to the temperature of formation of the Engels copper deposits. This they did by assigning a lower limit to the temperature of formation of ilmenite occurring in the deposit. This ilmenite contains hematite lamellæ of two distinct sizes regularly arranged in it and supposedly due to a separation on cooling of an originally homogeneous solid solution of ferric oxide in ilmenite. On this supposition the ilmenite must have crystallized at a temperature above that at which the hematite separated from the solid solution. For an actual temperature above which the set of smaller hematite lamellæ must have separated they referred to an earlier paper by Ramdohr (Ramdohr, P., Neues Jahrb. Min. Beil. Bd. 54-A, 320-379, 1926). Ramdohr's paper is discussed and it is found that it does not form an adequate basis for their assignment of a lower temperature limit.

The appendix, which is entirely theoretical, was added to aid readers, unfamiliar with equilibrium diagrams, to understand the discussion. It presents an equilibrium diagram for a hypothetical binary system in which the general relationships are similar to those supposed by Ramdohr to be shown by the system,  $Fe_2O_3-FeTiO_3$ . The reactions between the phases in certain typical cases of cooling are described.

- (779) Silicate structures of the cristobalite type. II. The crystal structure of  $Na_2CaSiO_4$ .  
III. Structural relationship of high-cristobalite,  $\alpha$ -carnegieite, and  $Na_2CaSiO_4$ .  
Tom. F. W. Barth and E. Posnjak. Z. Krist. 81, 370-385. 1932.

X-ray investigations of high-cristobalite ( $SiO_2$ ),  $\alpha$ -carnegieite ( $NaAlSiO_4$ ), and  $Na_2CaSiO_4$  have brought out an interesting and, so far, rather unusual

similarity in the crystal structure of these chemically very different silica compounds. (See also No. 771, the first paper of this series.) Since none of these compounds was obtainable in single, faceted crystals, X-ray diffraction measurements on powders and a few optical determinations constituted the whole experimental material. It was found that the atomic positions in high-cristobalite depend on six parameters, in  $\alpha$ -carnegieite on seven parameters, and in  $\text{Na}_2\text{CaSiO}_4$  on eight parameters. The structures of these compounds are thus so complicated that only a few years ago they would have been regarded as insolvable even if single crystals had been available. However, owing to advances made in recent years in the determination of the structure of crystals, our general knowledge of the structure of silicates has been so much extended that, even with the limited data which were available, it has been possible to establish the essential features of these structures.

In all silicates which have been studied so far it has been found that the main framework of their structures consists of large oxygen anions which are held together by small cations, chiefly silicon and aluminum. This has proved a useful guide in the present case, and a comparative description of the atomic arrangements found in these compounds, which are apparently so different chemically, brings out very clearly their close relation.

The structure of high-cristobalite,  $\text{Si}_2\text{O}_6$  (full formula for the unit cell), can be said to consist of a framework of silicon-oxygen chains extending along 6 different directions in space. In  $\alpha$ -carnegieite,  $\text{Na}_4\text{Al}_4\text{Si}_4\text{O}_{16}$  (full formula), the framework has the same configuration but half of the silicon ions are replaced by aluminum ions, so that the composition of the chains becomes: silicon-oxygens-aluminum-oxygens- . . . . . With this replacement of the tetravalent silicon ions by trivalent aluminum ions in the framework of  $\alpha$ -carnegieite four additional electropositive charges must enter the structural unit to balance the electronegative charges; these are the four sodium ions which are readily accommodated in the structure of  $\alpha$ -carnegieite by entering certain positions in some of the open spaces left by the chain formations.

In  $\text{Na}_2\text{Ca}_2\text{Si}_2\text{O}_{16}$  (full formula) the main framework is similar, only the chains are in this case made up of silicon-oxygens-calcium-oxygens- . . . . . With the replacement of the trivalent aluminum ions by divalent calcium ions in the framework of this structure, four additional electropositive charges must enter the structural unit to balance the electronegative charges. This requirement is accomplished by the entrance of four additional sodium ions which take up the last four available positions in the remaining open spaces of the  $\alpha$ -carnegieite structure. Thus it will be seen that  $\alpha$ -carnegieite ( $\text{NaAlSiO}_4$ ) and  $\text{Na}_2\text{CaSiO}_4$  are structurally closely related, and moreover, their structure is directly derived from one of the forms of silica, namely, high-cristobalite.

(780) An experimental investigation of the phase relations of  $\text{K}_2\text{Si}_4\text{O}_9$  under pressure. Roy W. Goranson and F. C. Kracek. J. Phys. Chem. 36, 913-926. 1932.

The phase relations of  $\text{K}_2\text{Si}_4\text{O}_9$  were investigated experimentally to 3000 bars pressure (metric atmospheres). Values were also obtained for the slope of the  $\text{K}_2\text{Si}_4\text{O}_9$  pressure-melting curve and for the heats of inversion and melting of  $\text{K}_2\text{Si}_4\text{O}_9$  at atmospheric pressure. In these experiments the  $\text{K}_2\text{Si}_4\text{O}_9$  solid  $\rightarrow$  liquid phase boundary (metastable above about 140 bars pressure) was obtained in all cases. In consequence of the metastable region some of the stable phase relations had to be obtained indirectly.

The results of such calculations were of necessity approximations because sufficient calorimetric and volumetric data were not available, but were nevertheless thought to be of some interest and therefore included.

The experimental results are tabulated below:

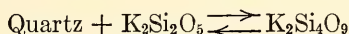
$K_2Si_4O_9$ . *Densities* at 25° C.: crystals, 2.33<sub>5</sub>; glass, 2.38<sub>4</sub>.

*Inversion curve*: inverts at 592° C. at atmospheric pressure; heat of transition is 9.6 joules per gram (2.3 calories);  $dt/dp = 28^\circ$  per 1000 bars; the calculated volume change on inversion, low  $\rightarrow$  high, is +0.003 cm.<sup>3</sup>/g. These values are reminiscent of the quartz inversion.

*Melting curve*:  $K_2Si_4O_9$  melts congruently at 765° C. at atmospheric pressure; heat of melting is 146.5 joules per gram (35 cal.); the initial slope of the pressure-melting curve is  $-60^\circ$  per 1000 bars, *i.e.* an increase of pressure lowers the melting temperature at the rate of 60° for each kilobar increase in pressure. This boundary curve was realized experimentally to 3000 bars.

$K_2Si_2O_5$ . *Density* of crystals at 25° C., 2.538; of glass at 25° C., 2.47<sub>4</sub>. The melting temperature is raised about 3.5° C. for each kilobar rise in pressure.

The following phase equilibria relations were obtained indirectly: Above 140 bars pressure  $K_2Si_4O_9$  melting becomes incongruent and the compound breaks up into quartz and liquid. Above about 1250 bars  $K_2Si_4O_9$  can no longer exist in equilibrium with liquid, but instead we have quartz and  $K_2Si_2O_5$  forming a simple eutectic. Further, since the reaction



probably can not be realized in practice, the presence of crystalline  $K_2Si_4O_9$  in a mixture of unknown origin would indicate that the silicate solution had crystallized below about 1250 bars pressure.

(781) The age of a monazite crystal from Portland, Connecticut. Clarence N. Fenner. *Am. J. Sci.* 23, 327-333. 1932.

A crystal of monazite derived from a pegmatite at Portland, Connecticut, has been analyzed for uranium, thorium, and lead, with the following results: U = 0.00 per cent; Th = 7.489 per cent; Pb = 0.1007 per cent. On the supposition that the lead has been derived from thorium by radioactive disintegration, an age of 277,900,000 years is calculated. This indicates a Devonian age.

Special interest is attached to this result from the fact that uraninite from the same quarry was analyzed by W. F. Hillebrand many years ago, and indicates an age of 282,900,000 years. The check is very gratifying, and gives additional support to the essential correctness and reliability of the principle by which the age of radioactive minerals is calculated.

Some of the subsidiary aspects of the matter are discussed.

(782) Some notes on the melting of granite. Roy W. Goranson. *Am. J. Sci.* 23, 227-236. 1932.

Since granite magmas contain water in solution and water acts as an effective "catalyst," experimental work was carried out on the fusion of Stone Mountain granite in the presence of water.

The granite, ground fine, and water were sealed up in platinum capsules and brought to the required temperature and pressure in a bomb. Pressure was obtained from the expansion of carbon dioxide, and temperature by means of a platinum resistance furnace enclosed in the bomb.



Equilibrium was difficult to obtain at temperatures below 800° C.; for example, 50 hours was required to fuse Stone Mountain granite at a temperature of 723° C. and under a water vapor pressure of 960 bars.

It is concluded that at  $700 \pm 50^\circ$  C. and under a water vapor pressure of 980 bars Stone Mountain granite will become essentially completely liquid, the resulting magma containing 6.5 per cent water in solution; that at  $575 \pm 50^\circ$  C. and under a water vapor pressure of 385 bars the granite will be 99 per cent + crystalline.

A calculation based on an assumed relation between liquidus temperature of granite and concentration of water gave  $1050 \pm 50^\circ$  as the liquidus of dry Stone Mountain granite. The general course of crystallization of a granite magma containing water in solution is then discussed.

(783) The cristobalite structures. I. High-cristobalite. Tom. F. W. Barth. Am. J. Sci. 23, 350-356. 1932.

One result of a previous determination of the crystal structure of cristobalite (Wyckoff, R. W. G., Am. J. Sci. 9, 448, 1925) is that the interatomic distance Si — O equals 1.54 Å. Subsequent studies of the structure of silicates have shown that this distance is unusually small. A re-examination of the structure of high-cristobalite revealed that Wyckoff's determination was not accurate; the actual structure is slightly different, and the interatomic distance was found to be Si — O = 1.63 Å.

(784) On the history and analytical expression of the first and second laws of thermodynamics, and the rôle of the differentials,  $dW$  and  $dQ$ . George Tunell. J. Phys. Chem. 36, 1744-1771. 1932.

As Clausius stated, the work done by a system and the heat received by the system are quantities the peculiarity of which is that, while their derivatives in definite directions are functions of the variables that determine the state of the system, the work and heat themselves can not be represented by such functions and can only then be determined when a further relation is given between the variables and the *path* of the changes is thereby fixed. Analytically the work and heat are therefore characterized as line integrals that depend on the choice of the path of integration.

The first law of thermodynamics, regarded as an empirical result of experience, is expressed analytically by the statement that the line integral representing the heat received minus the work done is independent of the choice of the path of integration. A necessary and sufficient condition that this integral be independent of the path is given, and is an equation that Clausius in Germany, Lord Kelvin in England, and Lippmann in France previously stated to be an analytical expression of the first law.

Similarly the second law of thermodynamics for reversible processes, regarded as an empirical result of experience, is expressed analytically by the statement that the line integral,  $\int \frac{dQ}{T}$ , is independent of the choice of the path of integration defining the changes of state of the system. Here  $Q$  denotes the heat received and  $T$  denotes some function of the temperature alone, the same for all systems, which therefore serves to define an absolute scale of temperature.

Most of the current texts on thermodynamics do not express the first and second laws explicitly in this way; and in many of them the emphasis is placed on differential equations that only constitute necessary conditions and do not constitute sufficient conditions to establish the truth of the first and second laws. The analytical expressions of the founders of thermo-



dynamics, Clausius and Kelvin, which are mentioned above, should be used rather than the differential equations in question. In their formulations Clausius and Lord Kelvin made use of mathematical theorems the proofs of which they did not introduce into their papers. Attention is called to clear and rigorous proofs of these theorems—indispensable in thermodynamics—that have been developed in recent years by Osgood.

- (785) The use of "ferrosilite" as a name for the normative molecule  $\text{FeSiO}_3$ . Henry S. Washington. *Min. petr. Mitteilungen (Z. Krist., Abt. B)* 43, 63–66. 1932.

It is suggested that the name "ferrosilite," with the symbol (fs), be used for the normative pyroxenic molecule  $\text{FeSiO}_3$ , instead of "hypersthene," recently proposed by Tom. F. W. Barth (Laboratory Publication No. 761). "Ferrosilite" was proposed and used by the author in 1903, but the term was published in an inconspicuous place, so that it has not come into general use. Remarks are also made on other features of the "Quantitative Classification of Rocks."

- (786) The volatility of silica with steam. George W. Morey. *Trans. Am. Geophys. Union*, 13th Annual Meeting, pp. 269–270. Nat. Res. Council, Washington, D. C. 1932.

In 1930, Van Nieuwenburg and Blumendal published results of experiments which indicated a marked solubility of silica in a compressed aqueous vapor, a solubility great enough to enable the transport of almost 0.3 gram of silica in twenty-four hours at  $390^\circ \text{C}$ . and a pressure of 300 atmospheres. So large a transport is not in harmony with what would be expected from experience with hydrothermal syntheses, and tests were made attempting to reproduce their results. Numerous experiments at various temperatures and pressures failed to confirm their results and gave amounts of transport that were about the limit of error of measurement and that were independent of the duration of the heating. The exact conditions of their experiments are uncertain. A pressure of 300 atmospheres at  $390^\circ$  can not be obtained without putting an amount of water in the bomb greater than the critical volume. The bomb would then be completely filled with liquid below the critical temperature, with opportunity for transport through a liquid phase, as well as by convective action.

- (787) Molecular rotation in the solid state. The variation of the crystal structure of ammonium nitrate with temperature. S. B. Hendricks, E. Posnjak and F. C. Kracek. *J. Am. Chem. Soc.* 54, 2766–2786. 1932.

The structures of three of the six crystalline modifications of ammonium nitrate have been determined, and data, leading to partial structure determinations, have been obtained from two other forms.

The nitrate groups are free to rotate in at least three orthogonal directions in the cubic (I) form which is stable between  $125.2$  and  $169.5^\circ$ ;  $a_0 = 4.40 \text{ \AA}$ ,  $1\text{NH}_4\text{NO}_3$  in the unit of structure.

The structural characteristics of the other modifications examined are:

Tetragonal (II) ( $125.2$  to  $84.2^\circ$ )  $a = b = 5.75 \text{ \AA}$ ,  $c = 5.00 \text{ \AA}$ ,  $2\text{NH}_4\text{NO}_3$  in the unit of structure.  $2\text{NH}_4$  at  $00, \frac{1}{2}, \frac{1}{2}$ ;  $2\text{N}$  of  $\text{NO}_3$  at  $0 \frac{1}{2}, \frac{1}{2} 0$ ; 2 oxygen at  $0 \frac{1}{2}, \frac{1}{2} 0$ ; 4 oxygen at  $x y, \bar{x} \bar{y}, \bar{y} x, y \bar{x}$ , with  $x = 0.14$ ,  $y = 0.36$ . The arrangement in the  $c$  direction was not determined.

Orthorhombic (III) ( $84.2$  to  $32.3^\circ$ )  $a = 7.06 \text{ \AA}$ ,  $b = 7.66 \text{ \AA}$ ,  $c = 5.80 \text{ \AA}$ ,  $4\text{NH}_4\text{NO}_3$  in the unit of structure. Space group  $Pbnm$  ( $V_{h^{16}}$ ), 8 oxygen in general positions with  $x = -0.07$ ,  $y = -0.27$ ,  $z = 0.06$ ; 4 oxygen on reflection planes with  $u_1 = -0.19$ ,  $v_1 = -0.05$ ,  $4\text{NH}_4$  on reflection planes with  $u_2 = 0.30$ ,  $v_2 = 0.52$ , 4 nitrogen of  $\text{NO}_3$  group with  $u_3 = -0.09$ ,  $v_3 = -0.19$ . The parameter values are probably accurate to  $\pm 0.03$ .

Orthorhombic (IV) ( $32.3$  to  $-18^\circ$ )  $a = 5.75$  Å,  $b = 5.45$  Å,  $c = 4.96$  Å, with  $2\text{NH}_4\text{NO}_3$  in the unit of structure. Space group  $Pmmn$  ( $V_h^{13}$ ) with 4 oxygen at  $x$  0  $y$ ;  $\bar{x}$  0  $y$ ;  $\frac{1}{2} - x$ ,  $\frac{1}{2}$ ,  $\bar{y}$ ;  $\frac{1}{2} + x$ ,  $\frac{1}{2}$ ,  $\bar{y}$ , with  $x = 0.19$ ,  $y = -0.095$ ; oxygen and 2 nitrogen at  $00u$ ,  $\frac{1}{2}$   $\frac{1}{2}\bar{u}$ , with parameter  $0.28$  and  $0.03$ , respectively, and  $2\text{NH}_4$  at  $0\frac{1}{2}v$ ,  $\frac{1}{2}0\bar{v}$ , with  $v = 0.57$ .

The form (V) stable below  $-18^\circ$  gives a powder diffraction pattern in agreement with a hexagonal unit of structure having  $a = 5.75$  Å,  $c = 15.9$  Å, containing  $6\text{NH}_4\text{NO}_3$ . The data indicate that the true lattice may be only pseudo-hexagonal. Diffraction patterns of samples at  $-33$  and  $-78^\circ$  are identical save for displacement due to expansion, despite the existence of a gradual transition at about  $-60^\circ$ .

(788) Spinel structures: with and without variate atom equipoints. Tom. F. W. Barth and E. Posnjak. Z. Krist. 82, 325-341. 1932.

The atomic arrangement in the unit cell of crystals having the spinel structure is of two different types:

Type 1. The normal spinel structure ( $\text{XY}_2\text{O}_4$ ) in which 8 X-ions occupy 8f; 16 Y-ions occupy 16c; 32 O-ions occupy 32b. Examples are  $\text{ZnAl}_2\text{O}_4$ ,  $\text{NiAl}_2\text{O}_4$ ,  $\text{CoAl}_2\text{O}_4$ ,  $\text{FeAl}_2\text{O}_4$ , and  $\text{MnAl}_2\text{O}_4$  (the value of the oxygen parameter,  $u$ , is in all these compounds about  $0.390 a_o$ ).

Type 2. The structure with variate atom equipoints ( $\text{YXYO}_4$ ) in which 8 Y-ions occupy 8f; 8 X-ions + 8 Y-ions occupy 16c; 32 O-ions occupy 32b. Examples of this type were found in  $\text{FeMgFeO}_4$  ( $a_o = 8.36 \pm 0.01$ ;  $u = 0.390 \pm 0.006$ ),  $\text{GaMgGaO}_4$  ( $a_o = 8.26 \pm 0.01$ ;  $u = 0.392 \pm 0.006$ ),  $\text{InMgInO}_4$  ( $a_o = 8.81 \pm 0.01$ ;  $u = 0.372 \pm 0.01$ );  $\text{MgTiMgO}_4$  ( $a_o = 8.41 \pm 0.01$ ;  $u = 0.390 \pm 0.006$ ),  $\text{FeTiFeO}_4$  ( $a_o = 8.50 \pm 0.01$ ;  $u = 0.390 \pm 0.01$ ), and  $\text{ZnSnZnO}_4$  ( $a_o = 8.61 \pm 0.01$ ;  $u = 0.390 \pm 0.01$ ).

(789) The existence of the high-temperature form of cristobalite at room temperature, and the crystallinity of opal. J. W. Greig. J. Am. Chem. Soc. 54, 2846-2849. 1932.

This note draws attention to two earlier publications of this Laboratory in which it was stated that cristobalite had failed to invert on cooling and had persisted at room temperature as the high-temperature modification. Additional examples of the phenomena are added and reasons are given for supposing that this is due in some way to the solid medium that in each of these cases surrounds these crystals.

It also mentions briefly that Dr. E. Posnjak has obtained an X-ray powder spectrogram from a sample of opal that agrees closely with that of the high-temperature form of cristobalite, thus confirming the recent announcement of Levin and Ott (J. Am. Chem. Soc. 54, 828-829, 1932). It is shown that the cristobalite crystals are here also dispersed in another solid phase.

(790) Über Schalter zur Eliminierung von parasitischen elektromotorischen Kräften. Walter P. White. Z. Instrumentenk. 52, 281-284. 1932.

Ebert and Lange have used a special plug contact to secure a switch for eliminating vagabond electromotive forces in work with delicate galvanometers. The device is excellent, but their method of using it is objectionable.

The details are rather technical.

First, they use it to short-circuit the thermel or other source of electromotive force, which alters the resistance of the circuit, and thus complicates greatly the correction for the vagabond electromotive forces. Second, they clamp wires on the contact blocks in a way which introduces a liability of

greater vagabond electromotive forces than those they avoid in their plug contact.

The two commonest methods of correcting without altering the circuit resistance are compared. These are, first, to reverse the principal electromotive forces, which reverses the effect of the others, and second, to remove the principal electromotive forces, leaving the others alone in the circuit for the moment, doing this so as to make no significant change in the resistance. The reversal method is a little more precise in some cases, and is easier to prepare for, which may be an advantage when various simple short jobs are to be done. The removal, or "cut-out" method, nearly as precise in any case, and often quite as much so, is easier to operate, giving every quantity as a single, direct reading, with little more than half as many observations as the other method requires. This feature is well-nigh decisive in its favor when various and frequent readings are made in the same experiment.

It is exceedingly easy to arrange so that the experimenter may have a choice between the two methods at any time.

- (791) Some correct and some incorrect statements of elementary crystallographic theory and methods in current text-books. George Tunell and George W. Morey. *Am. Mineral.* 17, 365-380. 1932.

In optical crystallography the following five terms are used very frequently by nearly all investigators and students: ray, wave-front, wave-normal, refractive index, and vibration direction. The meaning of each of the first three of these terms is understood and there appears to be no confusion in their use. Each of the last two terms is used in two different senses by different authors. The usages of the different authors are tabulated. The preferable usage of each term is given and the reasons why it is preferable are stated.

The various accounts of the immersion methods are discussed. The dispersion method was suggested by Merwin and Larsen; it was used and described by Merwin, and was applied later by Eskola and Tsuboi, each of whom stated the history of the method correctly. The statement of the history of the method given by Winchell differs from those of Eskola and of Tsuboi and is incorrect and misleading.

- (792) A review of "The microscopic characters of artificial inorganic solid substances or artificial minerals." By A. N. Winchell. George Tunell and George W. Morey. *Am. Mineral.* 17, 404-406. 1932.

A review of Winchell's collection of optical and geometrical crystallographic data, with specific comments on the data for a number of compounds quoted by Winchell.

- (793) An investigation of intermediate compound formation by means of the Raman effect. James H. Hibben. *Proc. Nat. Acad. Sci.* 18, 532-538. 1932.

The Raman spectra of a number of organic compounds, namely, croton aldehyde, aldol, olefines, and alcohols, were investigated. The results are consistent with their generally accepted chemical constitution. There is some evidence that aldol exists in a tautomeric form of the ketol type. Solutions of inorganic halides in organic solvents were examined. The normal spectra of  $\text{ZnCl}_2$  and  $\text{Al}_2\text{Cl}_6$ , as well as the solvent itself, show considerable modification when dissolved in methyl alcohol. This is interpreted as evidence of compound formation in solution. The principal line for  $\text{ZnCl}_2$  in ethyl alcohol remains unchanged. In aqueous solution the spec-



trum for  $\text{Al}_2\text{Cl}_6$  is approximately identical with that of the anhydrous material, favoring the presumption that the solution contains the halide as a polymer. The Raman water lines become similar to those obtained from crystal hydrates. Calculation of the approximate force constant indicates a polymerization through the chlorine atoms rather than the aluminum. The results with aluminum chloride hydrate and corundum indicate the probable screening effect of the water molecules in the former compound and are confirmatory of the ionic character of the lattice in the latter. Intensity changes on dilution found in the Raman lines with zinc chloride solutions may be attributed to a stepwise ionization process, undissociated  $\text{ZnCl}_2$ ,  $\text{ZnCl}^+$ ,  $\text{Zn}^{++}$ , and  $\text{Cl}^-$  being simultaneously present in solution. The Raman spectra of potassium sulphate and aluminum sulphate are identical with that found for potassium alum. Within the limits of the sensitivity of this method, therefore, no evidence was obtained for the existence of any potassium and aluminum complex in solution.

(794) Shift of the plane of projection in the gnomonic projection. F. E. Wright. *Am. Mineral.* 17, 423-428. 1932.

In the gnomonic projection the shift from one plane of projection to another can be accomplished graphically by several different methods; by their use the observer is able to locate the positions of diametral planes and of single points in the new projection. Several new methods, based on the isometric lines and their polar planes, are described briefly, together with the existing methods. The usefulness of the gnomonic projection as an aid in photogrammetric mapping from airplane photographs is emphasized.

(795) On bultfonteinite, a new fluorine-bearing, hydrous calcium silicate from South Africa. John Parry, Alpheus F. Williams, and F. E. Wright. *Mineralog. Mag.* 23, 145-162. 1932.

This mineral occurs in a huge inclusion or "horse" in the kimberlite pipe of the Bultfontein Mine at Kimberley, South Africa. It is associated with calcite, apophyllite, and natrolite. Its chemical composition is approximately represented by the formula  $2\text{Ca}(\text{OH},\text{F})_2\text{SiO}_2$ . It is easily soluble in weak hydrochloric acid and partially soluble in pure water, producing an alkaline solution. Specific gravity = 2.73; hardness, 4.5. Crystal system: triclinic;  $a:b:c = 0.6756:1:0.6873$ ;  $\alpha = 94^\circ 17'$ ,  $\beta = 91^\circ 59'$ ,  $\gamma = 90^\circ 44'$ . The crystals are small, water-clear prisms, 1 to 2 mm. long with poorly developed terminal faces; the crystals project commonly from the surface of radial spherulites. One large spherulite, 2 cm. in radius, is colored pink. Cleavage after 100 and 010 is fairly good. Fracture conchoidal; lustre, vitreous. The crystals are polysynthetically twinned after 100 and 010 with the result that each crystal is actually an interpenetrating group of twinning lamellæ showing four different orientations. The extinction angle on 010 is  $c : \gamma' = 27^\circ$  to  $29^\circ$ ; on 100,  $c : \gamma' = 46^\circ$  to  $48^\circ$ . Interference figures are difficult to obtain;  $2V = 70^\circ$ ;  $2E = 132^\circ$  with barely perceptible dispersion of the optic axes,  $2V_r > 2V_v$ . Optical character, positive. Refractive indices:  $\alpha = 1.587 \pm 0.002$ ;  $\gamma = 1.597 \pm 0.002$ ;  $\beta = 1.590$  (computed);  $\gamma - \alpha = 0.010$ ;  $\gamma - \beta = 0.007$ ;  $\beta - \alpha = 0.003$ . The optical orientation was ascertained chiefly by use of the Fedorov stage; without this method it would hardly have been possible to obtain satisfactory results. Bultfonteinite bears some resemblance to other fluorine-bearing, hydrous calcium silicates, especially custerite, but the differences between the two are sufficiently great to enable the observer to distinguish between them without difficulty.



- (796) The cristobalite structures. II. Low-cristobalite. Tom. F. W. Barth. Am. J. Sci. 24, 97-110. 1932.

The physical properties of the low-temperature modification of cristobalite are very little known. The reason for this is that no single crystals, either natural or artificial, are available; for low-cristobalite always occurs as an aggregate of extremely small units, on which neither goniometer measurements nor the usual optical determinations can be made.

It seemed as if an X-ray investigation of such crystals would help to increase materially our knowledge of this form of silica.

A series of X-ray spectrograms was therefore made, and an evaluation of all the data proved that the symmetry of low-cristobalite is orthorhombic, pseudo-cubic, with the axial ratio,  $a:b:c = 1.00:1.00:1.00 \pm 0.01$ . The space group is  $P2_12_12_1$ .

The paper also contains a complete determination of the atomic arrangement in low-cristobalite. All the atoms are, in general, points the positions of which are determined by 18 variable parameters.

A comparison with the crystal structure of high-cristobalite suggests an explanation of the mechanism of the high  $\rightarrow$  low inversion.

- (797) The system,  $\text{FeO-SiO}_2$ . N. L. Bowen and J. F. Schairer. Am. J. Sci. 24, 177-213. 1932.

The importance to petrology of silicates bearing iron in the ferrous condition has led us to investigate melting relations in the fundamental system involved, *viz.*, the system,  $\text{FeO-SiO}_2$ . The work was carried out by using crucibles of pure electrolytic iron as containers for the melts and an atmosphere of nitrogen as a protection against oxidation. It is found that iron can not reduce all the iron oxide of the melts to the ferrous condition; that all melts in equilibrium with iron contain some  $\text{Fe}_2\text{O}_3$ . The composition of the liquids can not therefore be accurately expressed in a binary diagram and the full relations are expressed only with the aid of a ternary diagram in which  $\text{FeO}$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{SiO}_2$  may conveniently be taken as components. The pure compound,  $\text{Fe}_2\text{SiO}_4$ , like ferrous oxide, and indeed all compositions on the  $\text{FeO-SiO}_2$  join, therefore melts incongruently with separation of iron.

The amount of this departure from a truly binary character is very small, especially for all compositions with enough  $\text{SiO}_2$  to render them of interest to petrologists. With great gain in convenience, the results may therefore be presented as a binary diagram by calculating all iron oxides as  $\text{FeO}$ . The "binary" diagram thus obtained shows a maximum at the composition of fayalite at  $1205^\circ$ , a eutectic between fayalite and tridymite at  $1178^\circ$  at the composition 62 per cent  $\text{FeO}$ , 38 per cent  $\text{SiO}_2$ , and a eutectic between fayalite and wüstite at  $1177^\circ$  and at the composition 76 per cent  $\text{FeO}$ , 24 per cent  $\text{SiO}_2$ .

To petrologists it is of importance that there is but one crystalline compound between  $\text{FeO}$  and  $\text{SiO}_2$ , the orthosilicate, fayalite. The synthetic mineral melts at  $1205 \pm 2^\circ$  and the natural mineral from Rockport, Massachusetts, at sensibly the same temperature. No crystalline compound of the composition,  $\text{FeSiO}_3$ , forms at any temperature where liquid occurs in the system, nor have we been able to find any evidence of its crystallization, even at temperatures as low as  $660^\circ$ .

The system is of much interest to metallurgists because it is the fundamental system of most slags. The results, therefore, give the melting temperatures of the pure iron silicate slags and indications of the thermal behavior of non-metallic (slag) inclusions in wrought iron and steel, as well

as of the composition of scale formed on these metals while being "worked" under certain conditions.

- (798) The effect of boric oxide on the devitrification of the soda-lime-silica glasses. The quaternary system,  $\text{Na}_2\text{O}-\text{CaO}-\text{B}_2\text{O}_3-\text{SiO}_2$ . George W. Morey. *J. Am. Ceram. Soc.* 15, 457-475. 1932.

Commercial glasses of the soda-lime-silica types do not consist solely of these three oxides, but in addition contain significant amounts of other constituents which are introduced incidentally as impurities or deliberately for some beneficial influence. Such minor additions may have either a favorable or unfavorable influence on the tendency of the glass to devitrify, and an investigation into the effect of such minor components is desirable. Previous results with  $\text{MgO}$  and with  $\text{Al}_2\text{O}_3$  have shown that a systematic study of a four-component system is necessary to the understanding of its devitrification relations, and that arbitrary and fragmentary excursions into such a system give little insight into the general effect of the minor constituent and may be misinterpreted to erroneous conclusions as to the effect of this constituent on glasses of slightly different composition. Accordingly, in taking up the study of the effect of  $\text{B}_2\text{O}_3$  on the devitrification of the soda-lime-silica glasses, it was added to 21 glasses in and near the field of devitrite,  $\text{Na}_2\text{O} \cdot 3\text{CaO} \cdot 6\text{SiO}_2$ , in the ternary system,  $\text{Na}_2\text{O}-\text{CaO}-\text{SiO}_2$ , in amounts up to about 5 per cent. In all cases the liquidus temperature was lowered, and the tendency toward devitrification reduced. Both of these effects are desirable, and add to the thermal stability of the glass. With glasses containing 10 per cent  $\text{CaO}$ , initially in the field of tridymite, or so near to it that a small addition of  $\text{B}_2\text{O}_3$  brings the resulting glass into the tridymite field, this initial lowering is replaced by an increase in the liquidus temperature, which passed through a maximum at from four to six per cent  $\text{B}_2\text{O}_3$ . With all other glasses the lowering continues, and the rate of decrease is greatest with glasses originally in the field of  $\text{Na}_2\text{O} \cdot 2\text{CaO} \cdot 3\text{SiO}_2$ . An exploration of the quaternary system showed that no new compounds are formed in any mixture that can be obtained by adding  $\text{B}_2\text{O}_3$  in amounts up to 50 per cent to any mixture in or near the devitrite field. It also indicated the probability that a narrow band of immiscible liquids is formed, extending across the ternary system,  $\text{CaO}-\text{B}_2\text{O}_3-\text{SiO}_2$ , and including the mineral danburite,  $\text{CaO} \cdot \text{B}_2\text{O}_3 \cdot 2\text{SiO}_2$ , but probably not extending far into the quaternary system. The fields of wollastonite and of  $\text{Na}_2\text{O} \cdot 2\text{CaO} \cdot 3\text{SiO}_2$  were found to sweep out regions in the quaternary system extending over the square,  $\text{Na}_2\text{O} \cdot \text{SiO}_2-\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3-\text{CaO} \cdot \text{B}_2\text{O}_3-\text{CaO} \cdot \text{SiO}_2$ , and the field of  $\text{Na}_2\text{O} \cdot \text{CaO} \cdot \text{SiO}_2$  was found to extend over the middle of this square, and is probably adjacent to the fields of wollastonite and of  $\text{Na}_2\text{O} \cdot 2\text{CaO} \cdot 3\text{SiO}_2$ . A compound is formed between  $\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3$  and  $\text{CaO} \cdot \text{B}_2\text{O}_3$ . There is included a general survey of the literature relative to the effect of  $\text{B}_2\text{O}_3$  on the properties of glass.

- (799) Annual Report for this year.

- (800) Equilibrium in binary systems under pressure. III. The influence of pressure on the solubility of ammonium nitrate in water at  $25^\circ$ . L. H. Adams and R. E. Gibson. *J. Am. Chem. Soc.* 54. 1932.

In continuation of the survey of the effect of high pressures on the solubility curves of ice  $\text{v}_I$  and salts in aqueous salt solutions outlined in the first paper of this series, the thermodynamic properties of solid ammonium nitrate and its aqueous solutions have been studied under pressures up to 10 kilobars at  $25^\circ$ . The specific volumes of solutions of ammonium nitrate

over the whole range of concentration at 25° and 1 atm. and the compressions of these solutions up to 10 kilobars were observed directly, and from them the partial volumes of the water and of the salt in the solutions were computed over the whole pressure and concentration range. The partial volumes of the salt do not exhibit the large increases with rising pressure that were observed in solutions of sodium chloride (Laboratory Publication No. 767), or potassium sulfate (Publication No. 777), except in the case of 15 per cent solutions where a small increase was noticed at low pressures. Indications are that above 5 kilobars the partial volume of the salt in solutions containing more than 15 per cent of  $\text{NH}_4\text{NO}_3$  is independent of the concentration.

From these data on the partial volumes, together with the values of the chemical potentials of the salt and water in solutions at room temperature and pressure, the solubility curves of ammonium nitrate<sub>IV</sub> and of ice<sub>VI</sub> were calculated exactly up to 12 kilobars and a pressure-concentration equilibrium diagram for the system,  $\text{NH}_4\text{NO}_3\text{--H}_2\text{O}$ , at 25° was constructed. The solubility of ammonium nitrate decreases continuously as the pressure is raised, diminishing from 67.6 per cent at atmospheric pressure to 43.6 per cent at 5 kilobars, 29.7 per cent at 10 kilobars, and 25.3 per cent at 12.1 kilobars, the eutectic pressure. At three points, namely, the freezing pressure of a 15 per cent solution, the pressure eutectic, and the concentration of the solution in equilibrium with  $\text{NH}_4\text{NO}_3$ <sub>IV</sub> at 12,300 bars, the diagram was checked by direct observation of equilibria and very satisfactory agreement was found.

- (801) The chemical composition of noselite and h  y  ne. Tom. F. W. Barth. *Am. Mineral.* 17, 466-471. 1932.

The chemical composition of noselite and h  y  ne has been the subject of much discussion. Since they both are rock-forming minerals, an accurate knowledge of their chemical composition should be of great value to petrology. By a study of natural and synthetic materials and by X-ray measurements, it was proved that the true chemical composition of noselite is  $\text{Na}_8\text{Al}_6\text{Si}_6\text{O}_{24}\cdot\text{SO}_4$ , thus confirming the assumptions of Morozewicz, Gossner, Brauns, and others. The general composition of the system of h  y  ne is  $(\text{Na}, \text{Ca})_{4-8}\text{Al}_6\text{Si}_6\text{O}_{24}(\text{SO}_4)_{1-2}$ .

Ever since Gmelin shortly after 1800 started to investigate h  y  ne chemically, mineralogists have been puzzled by this question. A mineralogical problem more than 100 years old has thus now been definitely solved.

- (802) The relation between the composition and the density and optical properties of glass. I. The soda-lime-silica glasses. G. W. Morey and H. E. Merwin. *Jour. Opt. Soc. Amer.*, 22, 632-666. 1932.

Measurements of density and optical properties have been made on 185 glasses of known composition in the ternary system,  $\text{Na}_2\text{O--CaO--SiO}_2$ , well distributed over the composition range from mixtures intermediate between the orthosilicate and metasilicate ratios to pure silica. The measurements include both unannealed and annealed glasses, and a special study was made of the effect of heat treatment on the properties of the glasses. Optical measurements include the refractive index,  $n_D$ , dispersion,  $n_F\text{--}n_C$ , and in addition, measurements of partial dispersion on glasses of extreme types. The relations between composition and properties are discussed, and it is concluded that no justification exists for an assertion that definite compounds exist in, and determine the properties of, the glasses. The specific refractivity as calculated on the hypothesis of additivity has been calcu-



lated by means of the Gladstone-Dale, Lorentz-Lorenz, Eykman, and Lichtnecker formulæ, and the same general pattern of percentage departure was found for all the formulæ tested. The Gladstone-Dale formula gives percentage departures that are little more than one-half as large as the others.

(803) Notes on the volatile transport of silica. J. W. Greig, H. E. Merwin, and E. S. Shepherd. *Am. J. Sci.* 25. 1933.

In the experiments on the melting of rocks, described in last year's report, the specimens were sealed in bulbs of silica glass and then heated in the electric furnace. It was found that at high temperatures silica was transferred in the vapor phase from the glass of the bulb to the enclosed charge, and deposited there.

The inner surfaces of the silica glass bulbs were coated with a crust of cristobalite. Because the crystals grow perched on the surface and not within the glass it seems probable that the silica to form this crust also moves through the vapor phase.

Experiments were made that show that the transfer takes place in the presence of either pure water or of the volatiles that are driven off from rocks when they are heated under low pressures, and that without these materials the transfer is inappreciable by the methods used.

The bearing of these experiments on the interpretation of natural deposits and on the possibility of volatile transfer in nature is briefly considered.

Attention is drawn to the striking effect of a small pressure of these volatile materials in lowering the viscosity of, and in inducing crystallization in, certain silicate liquids. This may be utilized to prepare suitable material for the study of equilibrium between crystals and liquid in silicate systems by enclosing the prepared glass, together with a small amount of these volatiles, in a bulb of silica glass and then heating in the electric furnace, controlling the time, temperature, and pressure to obtain the desired size and distribution of crystals in the glass.

(804) Crystallographic data on mellite. Tom. F. W. Barth and C. J. Ksanda. *Am. Mineral.* 18. 1933.

From X-ray data obtained from rotation, oscillation, X-ray goniometer, and Laue photographs the unit of structure of mellite was found to be a tetragonal prism the dimensions of which are  $a_0 = 22.0 \text{ \AA}$ ,  $c_0 = 23.3 \text{ \AA}$ ,  $a_0/c_0 = 1.055$ , comprising 16 molecules of the formula  $(\text{Al}_2\text{C}_{12}\text{O}_{12} \cdot 18\text{H}_2\text{O})$ ; calculated density 1.65. Although the geometrical and the physical properties of mellite correspond to a holohedral crystal symmetry, very definite space-group criteria indicate that the mineral is really isomorphous with  $D_4^3$  and/or  $D_4^7$ , two enantiomorphic groups in the trapezohedral class; mellite thus being the first known mineral exhibiting tetragonal trapezohedral symmetry.

The atomic arrangement depends on at least 240 parameters.



## DIVISION OF HISTORICAL RESEARCH<sup>1</sup>

A. V. KIDDER, CHAIRMAN

The Division of Historical Research comprises three Sections. The Section of Aboriginal American History concerns itself with studies relating to the rise of native civilization in the New World, its two principal fields being the Maya area in Mexico and Central America and the Pueblo area of southwestern United States. The Section of United States History is devoted to research upon the growth of Western European institutions in the Americas. The Section of the History of Science strives to bring together and to make available for interpretation the at present widely scattered and uncoordinated data which bear upon the acquirement and transmission of ordered knowledge.

### SECTION OF ABORIGINAL AMERICAN HISTORY

The two outstanding problems of pre-Columbian New World history are those of the peopling of the American continents and of the rise, in this hemisphere, of native civilization. The true position of the American Indian among the races of man can not be evaluated until we know who he was, and whence, why, when and how he came; nor can the significance of his career be understood unless we have information as to what elements of culture he brought with him, how much he developed independently, and how he managed to build up the complex social, religious and economic structures which he had possessed for centuries before the coming of Europeans. These two questions of origin and growth are naturally fundamental for Americanists; they are also of extreme importance for the study of anthropology in the broader sense, for the one strikes back to the primary diffusions of the human stock, while the second links into the vast riddle of man's perennial upward striving.

From the limitless range of possible activities in New World research, this Section has elected to devote itself to the rise of native American civilization; and, within that field, on the principle of nuclear attack, to operate in two regions whose people were preeminent as builders of aboriginal culture, the Maya area of Middle America and the Pueblo country in the southwestern United States.

The Section's early work upon the Maya was purely archeological. Its major effort is, indeed, still devoted to recovery, by exploration and excavation, of factual data bearing upon the prehistoric period. But as such materials began to accumulate, and an attempt was made to interpret them in terms of history, it became clear that temples and pottery and ornaments, even hieroglyphic dates, were, in themselves, relatively meaningless. It was perceived, as must inevitably occur in any archeological research, that very little progress could be made toward an understanding of how these things came to be what they were and where they were, to say nothing of what they meant, without accurate knowledge of a host of environ-

<sup>1</sup> Address: Room 909, Tower Building, Washington, D. C.

mental factors which the archeologist has neither the ability nor the time to study: the geology of the region, for example, its flora and fauna, its climate. Furthermore, there are certain flank-attacks, so to speak, which may be made upon archeological problems, advances along collateral lines which result in accumulation of data to supplement or to facilitate comprehension of the meager and fragmentary products of excavation. Documentary history offers one such approach by giving us, along with many other things, a picture of native life at the time of the conquest, which is indispensable for interpretation of ancient remains. Ethnologists, working on the present-day Maya, learn further facts useful for the same end. Linguistic study is an invaluable aid in that it permits deduction as to the specific and general relationships of groups, as well as concerning their contacts with people of other stocks. Racial questions must be considered in the light of data only to be gathered by the physical anthropologist. Medical research throws light upon the history of diseases. Agronomy tells us of the capabilities of the soil and the probable methods of its cultivation.

All this is obvious enough; or should be. But archeologists, like many other specialized workers in the human field, have been so busy with their own absorbing tillage that they have generally failed to realize the urgent necessity of developing some method by which the results of other disciplines may be made available for their use.

In an attempt to work out such a method, the Division has sponsored a general scientific survey of the Maya area. Its scope and the financial and organizational difficulties encountered have been discussed in a previous report.<sup>1</sup> The undertaking is still in the stage of experimentation. It has not been long enough under weigh to have permitted adequate testing of its more practical arrangements. One can not yet be sure of mustering the funds and the personnel which will be necessary to bring so many-sided a research to its logically full development. Mutually satisfactory relations must be established with a large number of cooperating agencies. The efforts of a very heterogeneous group of students must be coordinated and their diverse interests satisfactorily harmonized. But in spite of all uncertainties, in spite, too, of the briefness and inadequacy of the tryout, one may feel confidence in the soundness of this type of approach. For the activities of the collaborators, the historian, the linguist, the ethnologist, the physical anthropologist, have not only helped the archeologist, but have resulted in the formulation of a host of special problems of modern life which are themselves insoluble save on the evidence of what has gone before. Thus the present and the past have been firmly interlinked and the realization has been driven home that neither one can be understood save in the light of the other. So there has been a shift in emphasis, or rather a broadening of outlook; and what was originally the study of a single episode, the pre-Columbian era of Maya greatness, has become the envisagement of a continuously sweeping current of history. The biological, geological and climatological studies are likewise serving

<sup>1</sup> Carnegie Inst. Wash. Year Book No. 29, pp. 91-121.

to spread an environmental screen upon which the moving picture of a people's fortunes may be thrown in clear focus.

Few more favorable fields than the Maya country could be found upon which to come to grips with the fundamentals of history and of anthropology, nor for bringing about the much-needed recognition of the essential unity of their aims. Study of the Maya from the earliest times to the present involves consideration of age-long and world-wide problems: the relation of man to his habitat, the spread and interaction of nascent cultures, the origin of higher civilization, the decay and fall of social orders, the clash of native and European races, the adjustments between conquerors and conquered, the impact of Twentieth Century ideas upon backward populations.

It is difficult to escape the conviction that only by coordinated research, involving the cooperation of all the disciplines devoted to the study of man, and the collateral support of many biological and physical sciences, can we attain understanding of any given episode in human history. But any such research is obviously costly, complex and long. And when the anthropologist surveys the entire potential range of his labors, and realizes how rapidly are passing unrecorded away the languages and customs which are the very fundamentals of his science, he must inevitably feel that the mere factor of time can not permit him to spend his precious years or his limited funds in detailed work with less hurried colleagues in what is, from the total point of view, a very small corner of the field. He must harvest his whole crop before the devastating flood of Western European culture shall have washed it completely away. But in spite of all this, indeed because of it, there is a very real reason for carrying forward, concurrently with the essential salvage, a certain number of intensive projects in intimate association with other scholars. Anthropology, as a science, has not yet progressed sufficiently far to know just what facts are most essential for it to gather. Ideally, of course, everything should be observed and everything recorded. Practically, this is impossible. The ethnological field-worker must pick and choose. He can not, however, at this stage of the game, collect selectively without danger, nay without certainty, of missing vital data, because their bearing is not obviously apparent. Hence, both for the well-rounded growth of anthropology and for the immediate purposes of the great amount of raw collecting which it is our absolute duty to carry forward during the next few decades, it is necessary to test our methods and interpret our findings as we go along by the selection of certain significant groups which shall be studied both in historical perspective and from the viewpoint of environmental relationships, as well as with regard to their functional response to the exigencies of the modern world. No plea of urgency should influence us to forsake this indispensable type of research. As a matter of fact, the extensive and the intensive should proceed concurrently. Neither, in the long run, can be of full value if the other has been slighted. It is a firm belief in the truth of this proposition that has induced the Section of Aboriginal American History to undertake its present work in the Maya field.

Summaries follow of the various investigations carried on during the period from July 1, 1931, to June 30, 1932.



## ARCHEOLOGICAL RESEARCH

## CHICHEN ITZÁ

The work at Chichen Itzá, under direction of Dr. Morley, consisted of the excavation by Mr. Karl Ruppert of the Mercado, one of the largest Nahua-period buildings in the city; and the study by Mr. John S. Bolles of a highly important Maya-period structure, the Monjas.

The Mercado (English, *Market-place*—the name is a local one which probably has no significance, the structure having doubtless been erected for purely ceremonial purposes) forms the southern element of the great quadrangle known as the Court of the Thousand Columns, a plaza-like area of some six and one-half acres surrounded by colonnades and temples, the largest of which, the Temple of the Warriors, was excavated and repaired during the years 1925 to 1928 inclusive.<sup>1</sup>

The Mercado proved, upon investigation, to have consisted of a single-vaulted chamber no less than 250 feet in length, fronting upon the open expanse of the Court of the Columns, and communicating, by a doorway in the middle of its back wall, with a cloistered enclosure of rectangular form. Several ruined buildings, apparently very similar in plan and, therefore, presumably alike in function, have been identified by Mr. Ruppert in other parts of Chichen Itzá, but the Mercado, like most of the structures in the northern group, is conceived on a much more grandiose scale than the other examples of its type. The single vault, for example, is nearly 15 feet wide, the broadest span yet recorded from the Maya area; its cap-stones are unprecedentedly large and heavy; the thirty-seven alternating round and square stone columns which supported it on the front, and rendered it, in effect, a vast portico, are impressively massive. The architect of the Mercado was, it would seem, a man of bold ideas and much technical daring. But his creation held the weaknesses common to all Maya buildings; in particular it suffered from over-reliance upon inter-columnar beams of wood to carry the colossal load of the superstructure; and there is evidence that it crashed into ruin even before the abandonment of the city. Its fall, however, had covered in perfect preservation an altar, on which was sculptured in relief, and brilliantly painted, a procession of elaborately costumed captives, roped hand-to-hand, marching from either side toward a central enthroned figure.

The rear court is 130 feet square. It was surrounded by a cloister of slender, round columns 15 feet high, which bore a flat, probably thatched, roof.

Excavation of the Mercado brought the usual grist of problems. Such an undertaking involves two sets of objectives: archeological and preservational. For the purposes of archeology one seeks to derive every possible scrap of information regarding any given building: its groundplan and elevation, its decoration, the technical details of its architecture; one must attempt to learn its temporal relation to other buildings, to understand its function; and during the work one must gather all the collateral evidence that may be present in the form of pottery, implements, paintings,

<sup>1</sup> See Year Books Nos. 24 to 27 and *The Temple of the Warriors*, by E. H. Morris, A. A. Morris and J. Charlot, Carnegie Inst. Wash. Pub. No. 406.



sculpture and whatnot which bear upon the material and esthetic development of the ancient people. To collect the above data requires the most careful digging and the most intelligent and meticulous recording. These processes may perfectly well be carried out with no concern for the ultimate preservation of the structure itself. But the observations of the original investigator may be faulty; or he may overlook points of one sort or another which subsequent study prove to be of importance. Hence it is imperative that he leave the building in such condition that re-examination, by himself or others, is feasible. In some cases he can cover up what he has cleared, thereby saving it from further disintegration. Often this is the best method. But at a site as outstanding as is Chichen Itzá, visited by many archeologists and great numbers of laymen, it becomes essential to leave all major structures visible, understandable and sightly.

The preservation of an excavated Maya temple is a difficult matter. One must hold in their original position all elements found standing. To do this often requires extensive repair of weakened supports. Then there is the problem of how much that is fallen should be replaced. As a rule there are many parts of a building that lie, stone for stone, as they collapsed. There can be no shred of doubt regarding their former position. Should they be put back? There is always a strong temptation to do so, not only to render the structure more easily comprehensible, and because the scattered elements, if left on the ground, are exposed to all sorts of hazards; but also because one feels a duty, well expressed by Dr. Breasted during his recent visit to Chichen Itzá, to "fulfil one's obligation to the memory of the ancient architect." But restoration, once begun, is hard to stop; one move leads to another, with danger of error, with risk of destroying the psychological effect of a realization of time and change inherent in a ruined building. To say nothing of the expense.

At Chichen Itzá, Dr. Morley and his staff have very wisely governed themselves by circumstances. They have applied different methods to different units. Some temples, as the Xtoloc, have been held exactly as cleared; others, like the Warriors, have been rebuilt as far as there was absolute evidence for every step; one small one, the Temple of the Three Lintels, of which practically every stone was recovered, they restored completely. The Mercado might perfectly well have been put back almost block for block. Enough remained standing, however, to make it readily comprehensible. Decision was therefore made to hold it as nearly as possible in the condition in which it was found; certain columns of the portico were straightened; those in the cloister had fallen, so half of them were re-erected, the remainder cleared and left lying, drum by drum, as they had crashed; the main wall was strengthened and stairways, skewed and warped by tree-roots, were aligned and solidified.

The other major undertaking at Chichen Itzá during the 1932 season was the study, by Mr. John S. Bolles, of the Monjas, the largest and most complex of the few purely Maya temples erected at the site before the coming of Mexican influence stimulated the great building "boom" of later times. The Monjas, like the Mercado, bears a modern name, meaning in English "Nunnery," because of its many cell-like chambers. The use, however, to which it and many similar buildings throughout the Maya

area were put, remains problematical. This particular exemplification of the "Nunnery" or, as it is sometimes called, the "Palace" type is archeologically most important because it gives evidence of manifold remodelings and enlargements, no less than five distinct periods of architectural modification being evident, even on superficial examination.

The architectural problems of the Monjas can not be made clear without many diagrams and sections. Many points, indeed, are not yet understood. It suffices, therefore, to say that over and about an originally small building, there were erected a series of later ones, each larger than its predecessor; and that during the whole long process of growth there were tearings down, alterations, additions against and upon and around, the result of which is a veritable puzzle in massive masonry. But its very complexity gives the Monjas its significance, for it offers a most perfect case of architectural stratification, providing opportunity to recover irrefutable data upon the sequence of building processes and the devices of ornamentation.

Mr. Bolles naturally attacked the Monjas with due caution. He began his work by digging about the substructure of the latest increment in order to learn its relation to the many small ruins which lie close about it. This resulted, as seems always to be the case in Maya excavation, in the uncovering of a perfect mare's-nest of platforms and razed buildings, including the remains of a very large Nahua ball-court and of a whole series of late temples. Into the substructure of the Monjas two tunnels were driven, following the walls of an annex which disappears within it and whose relation to the main mass has not been understood. This mining operation served to trace the annex toward its original abutment against an inner substructure and to explain certain essential features of the growth of the whole complex. But the investigation has only just begun and, as is again always the case in Maya excavation, the problem at this stage has become far more involved than it seemed before work was started.

The question of the ultimate state in which the building is to be left is, however, a perfectly simple one. The Monjas is in relatively perfect condition, stands free of débris, its principal features are comprehensible without any restoration. Furthermore, it is a very beautiful ruin. Therefore it is obvious that it should be held in exactly the same condition in which it appears today. This is, as has been said, a simple matter—in principle. In practise it is far from easy, for it is much harder to solidify and keep from further disintegration a warped wall or the tottering blocks of a partly wrecked stairway, than it is to take them down and re-lay them. Such, nevertheless, must and will be done. The work of preservation was inaugurated this year by a difficult piece of emergency strengthening made necessary by two great caverns in the western part of the substructure, which seriously endangered the whole Monjas. These, with greatly appreciated financial cooperation on the part of the Mexican Government, were solidly filled, passages being left open to permit observation of buried structures and to serve as points of departure for new exploratory tunnels.

Other activities at Chichen Itzá were the partial clearing by Mr. Ruppert of an interesting group of small temples discovered by him in the dense

bush to the east of the Court of the Columns; and the commencement, by Mr. Strómsvik, of a highly promising comparative and analytical study of serpent columns. Dr. Hermann Beyer, whose services were most generously lent by the Department of Middle American Research of Tulane University, through courtesy of its Director, Mr. Frans Blom, spent several weeks at Chichen Itzá in a meticulously thorough examination of all the hieroglyphic material in the city. To three volunteer workers the Institution is indebted for extremely valuable services. Mr. John P. O'Neill surveyed the area in the northwestern quarter of the city necessary for completion of the topographic map of Chichen Itzá; he also mapped the Mercado and began detailed drawings of the mask-decorations of the Monjas. Mr. J. H. Denison jr. made rubbings of many inscriptions, developing a new and very satisfactory method for the recording of glyphs. Mr. W. L. Lincoln, who was at Chichen Itzá during the entire season, surveyed, made the color-record of the painted altar in the Mercado, mapped the ruins of Yaxuná, and conducted an expedition to Yaxhá in the Department of the Peten, Guatemala, where he prepared a map of the site for Dr. Morley's forthcoming monograph on the inscriptions of Peten. Dr. Morley, in addition to his duties as Director of the Chichen Itzá project, brought the above-mentioned monograph, the product of twenty years of exploration and study, to a stage verging on completion.

Throughout the season the staff were kept in touch, through the courtesy of Sr. Eduardo Martinez Canton, with his very important and spectacular finds in the excavations of the Mexican Government at the Castillo.

#### THE CALAKMUL EXPEDITION

Work at Chichen Itzá was interrupted, in mid-season, by word of the discovery of a large, hitherto unreported Maya city in the archeologically unknown forest region of south-central Campeche. Mr. C. A. Lundell, then in the employ of the Chicle Development Company, learning of the site from *chicleros*, explored and named it in December 1931, and later reported it to Dr. Morley, coming to Chichen Itzá in March, where he most generously turned over to the Institution his map and notes.

So important did the ruin seem, from Mr. Lundell's description, and so many inscribed monuments did it evidently contain, that it was decided to equip an expedition for its immediate investigation in order to take advantage of transportation facilities at the time available through operations of chicle workers in the region, but which might, in another year, not be available. Dr. Morley headed the party and handled the epigraphy; Mr. Ruppert accompanied it to report upon architecture; Mr. Bolles to survey the city; Mr. Strómsvik to turn fallen monuments and to study such artifacts and pottery as might come to light.

Four weeks were devoted to the trip, two weeks being spent at Calakmul. The five days' journey in from the city of Campeche by boat, mule-drawn trolley, auto truck and mule-back was arduous in the extreme. It was made possible by the most helpful cooperation of Mr. Brydon of the Chicle Development Company and the invaluable assistance of Sr. Francisco Buenfils of Merida, a large chicle operator. The ruins proved to be those of a very extensive Old Empire city. It is remarkable for the unprecedented-



edly large number of its monuments. No less than 103 stelæ were found, of which 75 per cent are sculptured, and of which the dates of nearly 50 were deciphered by Dr. Morley, covering the period in Maya chronology from 9.9.10.0.0 to 9.19.0.0.0 (364 to 550 A.D., according to the Morley-Spinden correlation). The height of ancient activity at Calakmul would thus appear to have taken place during the middle to later part of the Old Empire period. The nature of the sculpture indicates that the city was a thriving provincial center, evidently colonized from Peten. Its situation in a region between the previously known sites of Peten and those of later times in northern Yucatan gives it great archeological importance. Word of other large ruins in the vicinity, one of which was visited by Messrs. Ruppert and Bolles, and found to contain sculptured monuments extending into the 10th Cycle, offers ground for belief that much significant information upon Maya history awaits recovery in this region. It is planned to continue exploration there in 1933.

#### THE ARCHITECTURAL-CERAMIC SURVEY

As pointed out in previous Year Book reports, the outline of early Maya history has been based upon hieroglyphic dates. Dr. Morley's immediate chronological assignment of Calakmul, on the evidence of such inscriptions, is a case in point. For working out the actual story of the growth and decline of any given city, as well as for the placing of the many Old Empire sites which yield no dates, and practically all the ruins of the New Empire, one must, however, rely upon methods other than epigraphic. For such purposes ceramics and the details of architectural practise are by far the most easily obtainable and most surely reliable criteria available at the present time. Mr. H. E. B. Pollock has accordingly been devoting himself to the study of Maya architecture and Mr. H. B. Roberts to that of Maya pottery. During the past year they have combined forces to carry on a joint investigation in northern Yucatan, using Chichen Itzá as a base. The team attack has proved most satisfactory. On the practical side it naturally results in marked economy; intellectually it is a great advantage for two men approaching the same problem from different points of view to be able to keep closely in touch with each other's methods and results.

During the season of 1932 Messrs. Pollock and Roberts made three trips; two to the Puk region south of Ticul, where they worked at Sabacche, Muluc Seca, Xlabpak Maler and Labná; one to Yaxuná, a site some 12 miles south of Chichen, at which the ancient causeway running eastward from Cobá is thought to terminate. Mr. Roberts also visited Cobá to supplement, by pottery studies, the architectural observations made by Mr. Pollock in a previous year.

Ceramic research in the Maya area outside the Highlands of Guatemala is rendered difficult by the fact that surface sherds are either hidden by rank vegetation or are so weathered by exposure as to be more or less useless. It therefore became evident, early in Mr. Roberts' study, that some method must be developed for easily and economically collecting representative specimens from underground, and particularly for gathering material from places which would yield stratigraphic evidence. As rubbish



heaps naturally best fulfil the requirements of abundance of sherds and stratigraphic deposition, he has devoted much attention, at Chichen Itzá and elsewhere, to identifying the spots where the Maya were most given to dumping refuse. The result has been an increasing ability to locate heaps—off the edges of terraces, in corners of plazas, in low spots adjacent to temple-groups, etc. His trenches of 1932 at Chichen Itzá, in the Puk, at Cobá and Yaxuná have accordingly produced a great amount of broken pottery, so many thousands of pieces, in fact, that one of his major problems has been to keep their cleaning, sorting and classification abreast of their excavation.

Research upon the 1932 sherd collections is still in progress. It can not therefore finally be reported upon, but Mr. Roberts has already been able to recognize many well-defined types, to group these types into regional categories, and even to establish certain definite chronological relationships. In other words, the study of Yucatecan pottery is being placed upon a sound basis. Also, growing familiarity with the wares is permitting the quicker separation of what is of significance from what may safely be discarded in the field, thus sensibly reducing the amount of material which must be taken to the laboratory at Chichen Itzá, and so shortening the whole classificational process.

In addition to his strictly archeological work, Mr. Roberts has collected information as to the technique of present-day pottery making in Yucatan.

In his architectural investigation, Mr. Pollock has likewise been faced by difficulties in the collection and recording of data. Buildings abound, but they are, in many cases, so badly ruined that it is extremely hard to determine even their general layout and ground-plan, to say nothing of the details of their structure. Furthermore, while potsherds can be brought in for study, temples unfortunately can not, and full descriptive recording must be done in the field. This involves photography, and the making of sketches, plans and elevations, all time-consuming processes. Mr. Pollock has therefore not found it easy to keep pace, at such large sites as Labná, with the ceramicist. He believes, however, that with the assistance of a collaborator to help with surveying and photography, he can do so. His data, like those of Mr. Roberts, are not yet at a stage permitting conclusion. It may be said, however, that significant architectural diagnostics are beginning to be recognized, and that when similar studies are made of other groups, important regional and chronological differences will become evident. In the meantime Mr. Pollock has developed an extremely efficient method of note-taking and filing which not only permits instant comparison between analogous features of different structures, but which also brings his factual data into proper form for immediate publication.

#### UAXACTUN

The Section's second major archeological project in the Maya field is the excavation of Uaxactun, the Old Empire city in northern Peten, Guatemala, which was discovered by Dr. Morley in 1916, and at which, under the successive leadership of Frans Blom, O. G. Ricketson jr., Monroe Amsden, and A. Ledyard Smith, work has been carried on since 1924. Uaxactun was selected by Dr. Morley for intensive work because it was,

on the evidence of its hieroglyphic dates, both the oldest and the longest inhabited center of Maya culture. The digging of past years resulted in uncovering a very beautiful early structure embalmed, so to speak, within a later pyramid; and in the discovery of stratified deposits of still earlier times which carry the story of Maya development back to a period doubtless far antedating the first stone-carved records.<sup>1</sup> These very valuable finds, architectural and stratigraphic, were made in a quarter of the city known as E-Group. They amply justified Dr. Morley's selection of Uaxactun for investigation, in spite of its inaccessible situation and the consequent high cost of conducting excavations there.

In 1931, concurrently with the winding up of work in E-Group, Mr. Robert E. Smith commenced the study of A-Group, the largest and apparently the most important complex of buildings at Uaxactun. A spectacular find of mortuary pottery rewarded this effort.<sup>2</sup> During the past season the principal effort of Mr. A. Ledyard Smith and his staff, Robert E. Smith and Robert Wauchope, was devoted to further exploration of A-Group.

It will be recalled that the Monjas, or "Nunnery," at Chichen was so called because of its great number of small, cell-like chambers. Buildings of this sort, sometimes referred to as "palaces," are found in many parts of the Maya area. Their function is not as yet really understood, although, as the above names imply, they have been thought perhaps to have served as residences. The palaces of the Old Empire are very little known. Hence, in spite of the magnitude of the task, a large palace in the A-Group, structure A-V, was attacked this year by Mr. Ledyard Smith, reconnaissance digging in 1931 having indicated that under masses of fallen material the lower walls of many rooms remained in a good state of preservation.

The building, which rests on a low, roughly rectangular platform of masonry, is some 150 feet long by 130 feet wide. Its greatest height, as it now stands, is nearly 50 feet. The structure consists of four courts surrounded by blocks of cell-like chambers, whose vaulted roofs have, for the most part, collapsed. Of the four, the North Court and the Main Court, with the rooms adjoining them, were cleared during the season. The excavations showed that the courts lay on different levels, access from one to another having been gained by stairways. The rooms composing the blocks or galleries vary greatly in length; in width they run from 4 to 6 feet. Five constructions, tentatively identified as shrines, were found in the construction dividing the Main Court from the South Court. Each one consists of an anteroom and an inner chamber or sanctuary. In the sanctuary of Shrine I there was found a stela bearing the date 9.3.0.0.0. Under the stela was a cache of eccentrically chipped flints.

Throughout the palace Mr. Smith constantly noted evidence of changes in the building, old construction having been buried below later additions. There is an abundance of sealed doorways, and many rooms and even whole wings have been added. The palace was evidently at first a small structure, which grew by a slow process of accretion. Various peculiarities of architecture have been noted as characteristic of different periods. Three

<sup>1</sup> For accounts of the excavations at Uaxactun, see Year Books Nos. 25 to 30.

<sup>2</sup> See Year Book No. 30, pp. 110 to 112, and *Two recent ceramic finds at Uaxactun*, by A. L. Smith, Carnegie Inst. Wash. Pub. No. 436, 1932.

distinct types of rooms, for example, are already recognizable; and with complete excavation, which it is hoped may be accomplished in 1933, a true architectural stratigraphy should become evident.

Mr. Smith believes the palace to have been a dwelling place, because the walls of many rooms show evidence of cooking-fires, usually in sheltered corners; and because of the presence of debris of occupation in the form of animal bones, fragments of pottery and broken implements. The shrines, however, indicate that ceremonial practises were carried out in the building; and it is indeed possible that it was originally erected for purely religious purposes, the traces of a baser use dating from late times. Study of the pottery from the different levels and of the distribution of the areas smoked by cooking-fires may be expected to solve this problem.

While the excavation of the palace was going on, Mr. Robert Smith devoted himself to the examination of certain small pyramidal structures which, on the evidence of Pyramid A-I, excavated in 1931, might, it was thought, contain burial vaults. This work was planned with the double purpose of studying mortuary customs and of recovering, if possible, additional specimens of the finer sorts of pottery which, as a rule, can only be found in graves. The results were highly gratifying.

Pyramid B-VIII was first opened. From its summit platform a vertical shaft, the mouth closed by a red-painted stone slab, descended to a rectangular chamber 16 feet below. In the rough masonry of the chamber and of the shaft were footholds and offsets. On the floor lay the skeletons of two adult females, a child and an infant; fetal bones were intermingled with those of one of the adults. Seven pottery vessels, four plain, three with polychrome decoration, and some shell beads, constituted the mortuary offerings.

Pyramid B-XI, in addition to several caches of pottery and obsidian blades, yielded a coffin-shaped burial vault 7 feet long, 2 feet wide and 18 inches deep. One end was floored, walled and capped with massive stones; the other end, of much cruder construction, appeared to have been added at a later time. In the vault were the skeletons of two females, accompanied by pottery, a necklace of nearly five hundred shell and seven large jade beads, and another necklace of thirty-two beads of iron pyrites.

Against the base of Pyramid C-I, but evidently constructed before the erection of the pyramid, was a small room-like chamber 6 feet long, 4 feet wide and 5 feet high. On a low, centrally placed dais or altar were the bones of an adult male whose body had originally been placed in a sitting posture with legs crossed, Turkish fashion. Offerings were: four pottery vessels, one a black bowl with red and green decorations; an alligator-head pendant of jade, and the fragments of what had evidently been a mosaic mask.

Mr. Smith believes the vault in Pyramid B-VIII to have been a family burial chamber, the indications of such use being the several skeletons of various ages and the arrangement (removable lid, steps, etc.) for ready access to the tomb. The crypt in C-I, on the other hand, he tentatively identifies as a shrine in which the body of a notable, wearing a ceremonial mask and possibly prepared to resist decay, may have been placed for worship.



Less spectacular, but of doubtless even greater ultimate importance, was Mr. Robert Smith's discovery of a well-stratified rubbish deposit in the A-Group. Partial excavation of this midden yielded great numbers of potsherds, including a large percentage of pieces of the finer decorated wares. The material, being all of later date than that taken in former years from below the plaza of E-Group, will serve, when studied, greatly to lengthen the known ceramic sequence at Uaxactun; it will provide a key to the relative ages of the otherwise undatable isolated finds in caches and tombs; and it is hoped that it will link the Uaxactun series to that of Holmul, the only other city of the Peten whose pottery is now known.

Mr. Wauchope spent a considerable part of the season in a very careful examination of certain small elevations thought to be house-mounds. Of such mounds there are literally hundreds in the vicinity of Uaxactun. As they have been used as basis for estimates of population, it was thought desirable to continue the work begun on them in 1931, in order still further to check their identification as places of residence and to seek evidence regarding the domiciliary structures which may have been built upon them. Mr. Wauchope completely excavated four mounds; a fifth was less thoroughly investigated. Three proved to be typical house-mounds, long, narrow, artificially filled platforms with dressed limestone retaining walls; one or more terraces; and either plastered or unplastered floors, apparently once covered by perishable superstructures. The fourth was presumably religious in function. It consisted of a platform with a sequence of several plastered floors, upon the uppermost of which were low stone walls dividing the space into four very small rooms, probably once covered by a perishable roof. The fifth structure was the central element of a group, of which the fourth and one of the above-mentioned house-mounds formed the other units. The building had had masonry rooms with vaulted roofs. It is uncertain whether this was a residence more pretentious than usual, or whether it was a small temple, a shrine perhaps, for a group of dwellings. In the mounds, Mr. Wauchope found eleven burials, many stone artifacts, numerous potsherds and fourteen vessels.

#### THE GUATEMALA HIGHLANDS

Mr. and Mrs. Ricketson spent the winter in Guatemala, studying the collections from Uaxactun and writing a final report upon E-Group, which will be published in 1933. Opportunity was taken to examine various sites in the Highlands and a reconnaissance trip was made to Coban in the province of Alta Vera Paz, with a view to possible future excavations in that region. The Coban district is known to be rich archeologically and it is the Ricketsons' belief that its position on the northern slope of the Highlands, overlooking, so to speak, the Peten, makes it probable that Coban material might throw light upon the cultural relationships formerly existing between these two centers of Maya culture.

On July 17th Mr. Ricketson represented the Carnegie Institution at a special meeting of the Society of Geography and History of Guatemala, called for the purpose of presenting to the Institution a testimonial in appreciation of its scientific researches in Guatemala. Sr. Carlos A. Villa-



corta, the distinguished archeologist and president of the Society, delivered the address of transmittal.

During the winter of 1932 advantage was taken of the temporary residence in Guatemala of Dr. S. K. Lothrop to enlist his aid in carrying out a preliminary examination of the archeological remains on Lake Atitlan in the central Highlands. Dr. Lothrop most generously donated both his services and a large share of the expenses of the work.

Attempt was first made to conduct excavations at Chuitinamit, the traditional seat of the Zutugil rulers, a site of much importance because it is one of the few ruins in Guatemala where archeology joins hands with written history. Opposition by the Indians of Santiago Atitlan forced cessation of work after a few trenches had been dug. The large collection of potsherds made by Dr. Lothrop will, however, provide material for a preliminary ceramic study of Chuitinamit.

Attention was next given to a survey of the south shore of Lake Atitlan. The entire lake front at the base of the volcano Toliman proved to be a single continuous archeological site. Dr. Lothrop chose for investigation a locality known as Chukumuk on the summit of a ridge about  $2\frac{1}{2}$  miles from the town of Santiago Atitlan. He sank twenty-two test trenches which revealed débris of occupation to a depth of 8 feet, together with flexed burials accompanied by mortuary pottery; and a group of 8 decapitated individuals in the same grave, together with 22 pots and other artifacts.

The ceramic material comprises nine recognizable wares, whose stratigraphic and typological study indicates, in Lothrop's opinion, that the lowest Chukumuk finds have connection with early archeological horizons of the Valley of Mexico and of the Peten; as well as to the "Q" culture of eastern Salvador and the Chibcha culture of southern Central America. Intermediate Chukumuk pottery he considers to show relationship to later Peten and Copan wares, to Chorotegan incised and effigy types, and to Maya wares of Salvador and the Uloa Valley. The latest Chukumuk is of much more local significance. It links with that of Chuitinamit, Utatlan and other protohistoric and historic ruins. It is obvious that the Guatemala highlands hold the key to many of the most important archeological problems, not only of the Maya field, but of all Middle America.

In addition to the excavations of Chukumuk, examination was made of numerous house sites along the lake shores below Toliman of a type not previously encountered. Each house measured some 40 by 60 feet and had walls of dry stonework 4 to 6 feet thick. The interiors were divided into four to six rooms, some walls still standing 4 to 6 feet high.

Dr. Lothrop's forthcoming publication upon the work of the past winter will treat of the excavations and will contain notes upon other sites visited, both on Lake Atitlan and in the interior basins.

### COLLATERAL STUDIES

#### GEOGRAPHICAL RESEARCH IN GUATEMALA

Knowledge of the structure of the land and of its possibilities for use by man, together with information upon how modern populations avail themselves of its resources—in other words, materials of the sort gathered

and recorded by geographers—is essential both for an understanding of present-day life and for interpreting the necessarily meager and purely factual record compiled by the documentary historian and the archeologist. The special methods developed by geographers for the collection of data and for analyzing the complex interrelation between human beings and their physical and biological environments, should unquestionably be called into service in any such survey as that of the Maya area. Geographical research was accordingly begun during the winter of 1932 by Dr. Wallace W. Atwood, President of Clark University, who generously donated both his services and the expenses of his expedition; and by his son, Dr. Rollin S. Atwood of the University of Florida, the University cooperating most effectively by granting Dr. Atwood leave on salary during the period of the investigation, Carnegie Institution providing the funds for the research.

The Atwoods, with Mr. Webster McBryde, a graduate student of Clark University, took the field in February. The Highlands of Guatemala were chosen as the scene of the first year's work. Several considerations dictated the choice of this region. Most cogent was the fact that large Indian populations are still living there in more nearly their aboriginal condition than in any other part of the Maya area. Also, the region is most important archeologically, having been the seat of high cultures in late prehistoric times; as well as the probable home of the early peoples who are believed to have contributed elements to the very foundation of Maya civilization. Furthermore, the country is healthy and readily accessible; several other investigations are going forward there. Last, but by no means least, the government of Guatemala and its president, General Ubico, have been most helpful and cooperative in forwarding the Institution's scientific activities.

Dr. Wallace W. Atwood undertook the definition of the physiographic provinces of the central highlands, with special attention to study of Lake Atitlan and the territory immediately adjoining.

The most striking feature of the highlands is the chain of recent, and in cases active, *volcanic cones* which borders the region on the southwest. Many of the peaks rise to over 11,000 feet. They are but lightly etched by running water and for the most part are clothed with forests to within a few hundred feet of the summits. Most of the highlands under consideration are of volcanic origin, and by far the greater bulk of the material composing them is of fragmental nature. One explosive eruption followed another throwing ashes and dust high into the air. This material settled slowly and accumulated over the entire landscape. At several localities volcanic ash at least 3000 feet in thickness can be examined. Most of this material is of pumiceous character. Relatively few flows of heavy lava were noted. The huge cones are chiefly of basaltic flows, but the materials which compose the inhabited portions of the highlands are pyroclastic in origin. Thus the volcanoes that are conspicuous in the topography of today must be conspicuous in any analysis of the origin of land forms in this part of the Republic.

Related in origin to the volcanic peaks are the *modern ash basins*, large flat areas of pumiceous ash fallen, for the most part, from the air, but

also supplemented by intercalated and bordering deposits washed from adjacent slopes during and since the period of maximum volcanism. This ash lies in what appear to be old, relatively deeply eroded basins, filling them to an almost uniform level. Examples of such basins are the region of Guatemala City, that of Chimaltenango, the area between Chichicastenango and Santa Cruz Quiché, the vicinity of Quetzaltenango. Although he was unable to visit them, Dr. Atwood believes, from inspection of the relief map at Guatemala City, that there may well be others in the region of Salama, and another centering at Cubueco. The flat or gently undulating surface of the modern ash basins, and their fertile soil, have naturally made them focal points for agricultural communities where large populations can be sustained. The deep-cut gorges or barrancas, whose almost vertical walls testify to the recency of their origin and therefore to the youth of the deposits which they dissect, are eating rapidly into the basins and threaten seriously to reduce the area of farming land.

Bordering each of the modern ash basins studied are *older ash deposits* which are in a much later physiographic stage of development. Their topography is so rough that it should be described as mountainous. There are evidences of at least two cycles of erosion. During the first cycle a late stage of maturity was reached. Broad, open U-shaped valleys were developed. In the younger cycle, sharp inner canyons or gorges have been cut. These younger canyons or barrancas are now working headward and may be seen just below the upper U-shaped valleys in many of the mountainous regions. The older valleys of the first cycle or erosion are usually well cultivated. Drainage from them at many places falls or tumbles into the younger canyons.

Depth of weathering is greater and soil formation is much better in these provinces than in those that have been designated as modern ash basins. In many places, and notably along the road east of Los Enquentros, the black humus extends eight to ten feet below the surface. These rich soils have been discovered by the native Indian peoples of the highlands and many areas are under cultivation. Even the steep valley slopes have been cleared of their forest growth and planted each year for the production of corn and wheat. After a period of years the native people abandon a field which has been under cultivation and allow the forest growth to return, so that the landscape is distinctly patchy or spotted, cultivated fields alternating with forested areas. In many instances the cultivation is continued to the watersheds or divides, and this has resulted in considerable destructive erosion. In other places the timber have been allowed to remain, and in the region of Chichoy hill there is a magnificent forest which appears never to have been completely removed.

The large communities or villages are not located in these older areas of ash deposits. The landscape is dotted with little thatched roof cabins where the native people make their homes. They live near their fields and have the custom of going each week to market in some neighboring village.

#### THE ANCIENT CRYSTALLINE AND METAMORPHIC AREA

In the political province known as Totonicapan and northward into the political province of Hushuetenango, Dr. Atwood identified sufficient ex-



posures to demonstrate the presence of a much more ancient geologic foundation than had been found in any of the other areas studied during the past season. In this physiographic region there are deeply weathered granites, various micaceous schists, quartzites, conglomerates, ancient coarse-grained volcanic breccias, and various types of ancient lava flow. Structurally this region has the character of an ancient massif, and yet there is in many places a mantle of relatively recent volcanic ash. This most ancient of the physiographic provinces thus far defined probably extends far to the northward and westward of the route along which it was examined. East and northeast of Guatemala City along the route of the railroad to Puerto Barrios there are exposures in ancient metamorphic rocks, lava flows and breccias that indicate that the topography in that region, preceding the relatively recent and violent volcanic activities in the Highlands of Guatemala was much more rough or mountainous than it is today. That area was not seen in sufficient detail to be classified as a physiographic province, but from travel along the railroad the hypothesis was formulated of an ancient mountain area of complex structure and metamorphosed rocks in which the elevations were buried up to their shoulders in volcanic ash.

#### RECENT ALLUVIUM

In the Highlands of Guatemala the extent of recent alluvial deposits is very slight. This is a region of extreme youth from a physiographic standpoint. The streams have not had time in the present cycle of erosion to develop broad flood plains. There are a few small deltas and torrential fans about the shores of Lake Atitlan. They have been discovered and pressed into use by the native people who are always on the search for more good lands where food may be produced. About the shores of Lake Atitlan and southwestward along the outlet drainage from that lake there is a little alluvium. When physiographic studies are extended into some of the old parts of Guatemala and into the coastal lowland bordering the Pacific Ocean, much larger areas of alluvium will be discovered.

#### LAKE ATITLAN

Dr. Atwood devoted special attention to Lake Atitlan which, he believes, is a great crater lake or, most properly speaking, a caldera. If so, its rim-to-rim diameter of some 12 miles makes it one of the largest, if not the largest, in the world. Evidence in support of the caldera hypothesis is furnished by the vertical, faulted faces of the spurs between the valleys cut into the walls for the basin; by the outward dip of lava flows and ash beds in the wall; and by the uniformly great depth of water (1000-1100 feet). The volcanoes Toliman and San Pedro, which tower some 6000 feet above the lake's surface, are, in Dr. Atwood's opinion, of much more recent origin than the caldera.

Within the great caldera occupied now by Lake Atitlan there are no less than nine Indian villages that are situated but a few feet above the water level. Within the present drainage area and located 1000 to 2000 feet above the waters of the lake there are six others. The native people have chosen the deltas and the torrential fans for their settlements in some



instances, but in at least two they have placed their homes, in order not to invade the agriculturally precious alluvium, upon lava flows and have built their houses of blocks of basaltic lava. The many ruins observed by Dr. Lothrop testify to a dense aboriginal population (see p. 101).

In closing his preliminary report, of which the preceding paragraphs are a skeleton summary, Dr. Wallace W. Atwood expresses the opinion that Guatemala offers to the physiographer a most fertile and important field.

Dr. Rollin S. Atwood had as objectives for the season: to size up the geographic problems of the Highlands as basis for a definite program of future activities; and to undertake a detailed geographic survey of a typical area. The region of Chichicastenango was selected for the intensive study, headquarters being made at the residence of Padre I. H. Rossbach, the representative of the Catholic Church at that city, a gentleman whose hospitality, scholarship and unfailing helpfulness have done so much to facilitate and to render pleasant the work of all scientists who visit his parish.

The town of Chichicastenango with its adjacent villages has a population of about 30,000, composed almost exclusively of Indians who maintain to a remarkable degree their native individuality. It lies near the center of one of the great ash basins described by Dr. W. W. Atwood. The preliminary examination of the region gave the impression that the population is more or less evenly distributed. A more careful study, however, showed that all the large present-day villages and, in most cases, even the small settlements are located in direct relation to the physiographic features which control the water supply. It also became apparent that changes in the water table have resulted in abandonment of certain areas occupied in ancient times.

The foundation of all life and work in the Highlands of Guatemala is agriculture. In the Chichicastenango basin it is predominantly the growing of corn, wheat, and beans. Wheat, due to its ability to withstand lower temperatures, is grown in the "high *cantones*" on the maturely dissected rim of the basin. Corn holds full sway throughout the inner basin, but because of the universal demand for it and the enticingly rich soils of the higher, colder and rougher regions, is also cultivated on the rim. The planting near Chichicastenango takes place after the second heavy rain, which usually comes about the middle of May. Cultivating is done about every six or eight weeks throughout the rainy season, which lasts until about the middle of October. In November the "*puntas*"—sections of stalk above the ears—are cut off to stop further growth, and the ears are allowed to ripen and dry out until the middle of December, when they are harvested. During the entire growing season the Indians carry on more or less elaborate religious ceremonies.

Although practically every Indian in this region is engaged in agriculture, there are scarcely any who work solely on their land the year around. Out of a total population of approximately 30,000 it is estimated that slightly less than 8 per cent do part time work on the coffee and sugar fincas near the coast. Almost all adult male Indians who do not work on fincas engage to some extent in commerce. A few of the less energetic

are satisfied with carrying their 75- to 90-pound loads of produce each week to the local market of Chichicastenango. For many of these, this means a long journey over narrow and steep mountain trails. The large majority, however, not content with doing merely local business, travel on foot from one market to the next, selling and buying at each one. Thus there is produced a network of trade which covers the entire Republic and extends far beyond its borders. The careful tracing out of this commerce is essential for understanding the social and economic life of the Highlands. Its roots, too, doubtless go back to prehistoric trade. Dr. Atwood studied the markets of the several towns visited, noting the major products bought and sold in each. He made a very detailed investigation of the market of Chichicastenango.

In the Chichicastenango region, industrial development, as it is known in the United States, is entirely lacking. Manufacturing is in the early handicraft stage and is practically limited to products used by the Indians themselves. Detailed descriptions of the major industries were recorded and an economic and industrial survey of the town itself was made.

Both Dr. W. W. and Dr. R. S. Atwood report that the lack of a good topographic map of Guatemala greatly handicaps all geographical work. They stress the fact that the detailed observations necessary for solving the geological and physiographic problems of the Republic can not well be made, nor can data from different regions be correlated without maps far more accurate and upon larger scales than any which now exist. And the essential investigations in human geography: the studies, for example, of soil utilization, of distribution of crops, of land ownership and of village boundaries, also urgently require adequate maps to serve, at least, as the basis for sketch enlargements to be made in the field. The Guatemalan government is not at present able to undertake the necessary surveys, but its enlightened attitude toward all scientific activities renders it probable that every possible aid would be given. Attempt is therefore being made to bring about this badly needed and, intrinsically, very interesting cartographic project.

Mr. McBryde's work consisted of an intensive study of Sololá, a thriving Indian community perched far above Lake Atitlan on the rim of the great caldera. He prepared a traverse map of the town and immediately surrounding country, showing physical features, such as hills and streams; and cultural features—streets and roads, ditches, aqueducts, buildings of all sorts. For the central part of the town was recorded the distribution of stores, administration buildings, churches, residences, etc. The map also indicates the use of non-urban land, showing crop distribution, pasture and forest. Notes were taken upon crops, growing seasons, agricultural methods, political organization, industries, religious ceremonies in relation to planting, to harvest and to market; upon artisans—the distribution of their shops, and where, generally, they learned their trades. He collected climatological data, census material, and made a complete photographic record.

To the market Mr. McBryde, like Dr. Rollin Atwood, paid special attention. He listed all commodities sold, with names in Spanish, Cakchiquel, Quiché and Zugtuhil, and prices. On four weekly market days he gathered,

with the help of native assistants, a detailed record of all Indians entering Sololá, of their provenience, and of their loads both coming and going. This record is supplemented by a map of the market place locating every vendor by sex, town of origin and commodity sold.

MEDICAL RESEARCH IN YUCATAN AND GUATEMALA, BY  
DR. GEORGE C. SHATTUCK<sup>1</sup>

The Third Yucatan Medical Expedition: George M. Saunders, M.D., Clinician, in charge; Frank H. Connell, Ph.D., Protozoologist; Byron L. Bennett, Laboratory Technician, was in the field from June 23 to September 23, 1931. The primary purpose of the expedition was to collect information upon the various forms of malaria and amoebic dysentery. The investigations of 1929 and 1930 had thrown much light upon the prevalence and distribution of disease in general in the State of Yucatan, but had provided insufficient data of this kind about the above two diseases, which are of special importance as causes of morbidity and of mortality in many tropical countries. Statistical data indicated that both malaria and amoebic dysentery are far more prevalent in Yucatan in the summer than in the winter and, consequently, it became clear that observations relating to them could best be conducted in the summer. Dr. Saunders' expedition not only undertook to do this but also to add to the series of blood-pressure measurements, a considerable number of which had been made by the other expeditions, and which indicated that excessively high blood-pressure is uncommon in Yucatan and particularly so among the Maya, their average blood-pressure being apparently distinctly less than that of the United States or Europe.

The nature of the investigation required the making of observations at a number of different places scattered over the State. A minimum of eight localities was selected, it being left to Dr. Saunders to cover others if time should permit. By energetic and rapid work his expedition succeeded in holding a series of clinics and in making the needed observations in 11 towns or villages; Merida, Progreso, Chichen Itzá and vicinity, Valladolid, Temax and Buctotz, Muna, Peto, Izamal, Dzilam Puerto and Telchac. On the average, about a week was spent in each place. This expedition was beholden to the Governor of Yucatan, Sr. Bartolomeo Garcia Correa, and to numerous town officials, and to Sr. Fernando Barbachano P. for kind cooperation in furthering its objects.

The findings of Saunders and Connell indicate that infestation with amoebæ of the type which cause dysentery is extremely common in Yucatan and it seems highly probable that this organism is in fact a serious menace there not only to health but also to life. The presence of the three types of malaria in Yucatan was demonstrated by finding the three varieties of malarial organisms, but comparatively few of the blood examinations made showed the presence of plasmodia. It appears, therefore, that although malaria has undoubtedly prevailed to a serious degree in parts of the State of Yucatan at various times, the disease was not very common in that State during the summer of 1931. Malaria in Yucatan is by no means the scourge that it is in most tropical countries. Undoubtedly, one reason for this is the comparative scarcity of surface water in which the mosquito

<sup>1</sup>The health survey of the Maya area is a joint undertaking of the Department of Tropical Medicine of the School of Public Health of Harvard University and Carnegie Institution of Washington. For reports upon the work of previous years, see Carnegie Inst. Wash. Year Books No. 28, p. 301; No. 29, p. 110; No. 30, p. 119.



vector might breed. The blood-pressure observations, in general, confirmed and strengthened those of the earlier expeditions.

The data obtained by Dr. Saunders' expedition form Part III of the full report of the three medical expeditions to Yucatan, now in press for publication by Carnegie Institution under the title of "The Peninsula of Yucatan."

The First Guatemala Medical Expedition: George C. Shattuck, Clinician, in charge; Wilhelm Curth, M.D., Dermatologist; Carlos Sanchez, A.B., Secretary and Interpreter; Byron L. Bennett, Laboratory Technician, was in the field from January 30 to March 22, 1932. Its objectives were: (1) To gain a general knowledge of the diseases prevalent in the Highlands of Guatemala. (2) To compare the observed conditions with disease conditions in the low Yucatan Peninsula with special reference to the Indian population, their mode of life, and other factors which might have a bearing on their health. (3) To obtain the fullest possible data upon the frequency and severity of syphilis among the Indians, as well as among the Ladinos (mixed bloods) of this region. (4) To collect available statistical data upon mortality and morbidity in Guatemala as a whole. (5) To gather available climatological data.

Comparatively little has been published of a specific or even of a general nature about disease in Guatemala, so that there was needed a good deal of first-hand clinical information, as well as general information of the sort to be had by interviewing informed people on the ground. It was thought that differences in the prevalence of disease might be correlated with mode of life and climate and that certain inherent weaknesses or resistances of the Indians might be thrown into relief by comparing the health status of the Indians in the Guatemala Highlands with that of the Maya of the Lowlands of Yucatan.

It was not believed so important to study disease on the coastal plain as in the Highlands because on the coastal plain the climate and environment is essentially tropical and there was every reason to expect to find there the usual diseases of the American tropics. Moreover, the prevalence of malaria and dysentery there was well known through the hospital work of the United Fruit Co.; and the Rockefeller Foundation had made special studies of the distribution of hookworm disease and of malaria in Guatemala.

A problem of far-reaching importance had been invisaged in Yucatan where it appeared to be a fact that the Maya have an extraordinary resistance to injury and perhaps also to infection by the virus of syphilis. This suggests that syphilis is an old disease among the Maya, and that, in consequence, they have acquired a higher degree of immunity against it than has been demonstrated in any other race. This hypothesis has an important bearing on the history of syphilis by implying that the disease existed in Central America long before the Conquest, that it originated there, and that it was first brought to Europe from the New World by the sailors of Columbus. Belief in an American origin of syphilis has long been held by many, but opponents still insist that it is much older in China than in Europe and that it came to Europe by way of the East. These considerations, and the doubts cast by expert serologists upon the above interpretation of our findings in Yucatan, caused the inclusion in the Guatemala Expedition of Dr. Curth, a specialist in skin diseases and syphilis.

After consultation with Dr. Kidder and others, plans were made to study the Indian and Ladino inhabitants of the villages about Lake Atitlan. Reconnaissance of the region led to choice of Panajachel as a base, and the



laboratory was set up there in the school-house. Introductions to officials had been most kindly furnished by General Ubico, President of the Republic, so that their cooperation was readily secured. It remained, however, to gain the confidence of the Indians in order that they would come to our clinics for examination and treatment and would willingly permit us to take samples of blood to be subjected to serological examination for syphilis. Mr. Carlos Sanchez, who was sympathetic to the Indians and who knew personally some of those living about the Lake, not only served as interpreter, but was of inestimable service in winning for us the good will of all classes of people of the region, with the result that we had an adequate supply of patients and no time was lost at Atitlan. At Chichicastenango, where a few clinics were held, Padre Rossbach helped us in the same way. The work went forward so rapidly that there was time to accept the invitation of Mr. Gordon Smith to continue our work on his coffee plantation. Although he had anticipated no difficulty, the Indians proved refractory and little was accomplished in the week spent there.

As result of the investigation, dysentery was found to be by no means as prevalent in the Highlands of Guatemala as in Yucatan. Malaria of importance is found only in a few villages on the shores of Lake Atitlan. Hookworm disease is scarce, and when seen has always, or nearly always, been contracted during periods of work upon the plantations on the coast. In general, diseases in the Highlands are those of the temperate zone rather than of the tropics. Tuberculosis, rheumatic fever, cancer, and the degenerative diseases which affect the arteries, the heart and the kidneys, are notably unusual outside the large towns and cities. This is true not only in Guatemala but also in Yucatan.

As in Yucatan, so also in Guatemala, those of pure Indian stock, and to a less degree those having a large admixture of Indian blood, show an extraordinary resistance to damage of the virus of syphilis. Careful physical examination by Dr. Curth and 500 serological tests (300 on Indians and 200 on Ladinos) support this statement.

In the course of our work two other conditions were noted; namely, the prevalence of goiter and the high cost of quinine, which puts this drug beyond the reach of most of those who suffer from malaria. The President of the Republic, other high officials of the Government, and representatives of the United Fruit Co. all became interested in the suggestion that quinine for home consumption might be produced at minimum cost in Guatemala to the advantage of all concerned; and the Director General of Health accepted with alacrity an offer to collect and send him recent literature upon methods of preventing goiter.

#### NUTRITIONAL AND ANTHROPOMETRIC STUDIES

By far the most important of the manifold practical problems of human existence is that of filling the stomach. Men must be fed before any other activity can be undertaken. The quality and quantity of their food determines their health and vigor; the ease or difficulty of its attainment regulates the amount of effort they may put into activities beyond and above the mere business of keeping alive. Food supply and physical environment interlock to produce the most cogent conditioning factors of any people's career. No anthropological or historical investigation can therefore strike very deep without taking them both seriously into account.

In research upon the Maya, questions of food arise at every turn. Interpretation of the findings of archeology hinges, for example, very largely

upon understanding of how it could have been possible for this race to have wrested a bare subsistence from a region at once so thin-soiled and so densely jungled, to say nothing of having garnered sufficient surpluses to have enabled them to devote obviously large amounts of their time to such superfluities as the building, without the aid of metal tools, the wheel, or beasts of burden, the huge religious structures with which many parts of their former range are literally crowded. All calculations of ancient population must be based upon estimates of the country's crop capacity; all judgment of the physical condition of the modern Maya must rest upon knowledge of the nature of their food.

An illustration of the last statement is provided by the inquiry into the basal metabolism of the Maya. Dr. Williams' original determinations, made at the instance of Dr. Benedict of the Institution's Nutrition Laboratory, showed the Maya to be paradoxical in possessing a very high metabolic rate combined with an abnormally low pulse. Dr. Shattuck's check confirmed Williams', and Dr. Steggerda's most carefully controlled recheck placed the matter beyond dispute. This extremely unusual condition may be, it is thought, innate, in which case it becomes a most useful criterion of race. It may be caused by action of the cold Yucatecan nights upon thinly-clad, blanketless hammock-sleepers. If so, it may have important bearings upon study of the functioning of the ductless glands. But, in either case, the problem can not be settled until we know exactly what the modern Maya eat to produce the bodily activities expressed by the basal metabolism measurements.

So both archeology and physiology need information regarding food. And widely separated as are the problems which they seek to solve, they both, together with the many other inquiries which are also brought to grips with questions of nutrition, come down, in the last analysis, to insistent demand for a single piece of primary data: the man-per-day ration of the Maya Indian.

This seems a simple matter. But surprisingly enough, one discovers that the best we can offer is the vague statement that the Maya live largely on corn, in the form of *tortillas*, eked out by a certain amount of beans and other vegetables and a little meat. The exact amounts consumed, the quality of the various comestibles, the nature of their preparation; of all such things we are completely ignorant.

A start toward remedying this unfortunate situation was made during the past winter at Chichen Itzá by Dr. Steggerda, who, after learning the necessary technique in Dr. Benedict's laboratory, collected and preserved 65 food samples. He also made exact record of everything eaten by four Maya men for three successive days. The material has been sent to the Nutrition Laboratory for analysis. Many further observations will, of course, have to be made in different parts of the region, during all seasons, and upon people of various ages, economic positions and occupations.

While we are still upon the subject of food, it may be permissible, before taking up Dr. Steggerda's other work in Yucatan, to mention a second aspect of the matter which has not yet been given adequate attention. Before consuming his food, man must get it. The Maya staple is, and evidently for a long time has been, corn. Therefore of equal importance

with the man-per-day ration is the corollary problem of the bushel-per-acre capacity of the land. This, again, is unknown, although several years ago Mr. O. F. Cook of the United States Department of Agriculture, made, at Dr. Morley's suggestion, a beginning of such a study. It is imperative that it be continued. We must go into the whole agronomic situation, Highland and Lowland, in the greatest possible detail, learning from the historian all we can of farming practise at the time of the Conquest, from the ethnologist how the modern Indians sow and harvest, from the geologist and geographer the nature and extent of cultivable terrain, from the soil chemist its potentialities.

To return to Dr. Steggerda. This gentleman's collaboration in the survey is made possible by the Institution's Department of Genetics. His primary interest is in the genetic aspects of physical anthropology. He has carried on the anthropometric work begun by Dr. Williams and has added thereto a study of Maya growth, selecting, for continuing observation, with the expectation of following them year-by-year through adolescence to adult life, the children of Pisté and Chan Kom, Indian villages in the neighborhood of Chichen Itzá. For comparative purposes he is about to start a parallel study of Navajo Indian children in Arizona. He is also collecting data regarding certain large family groups. In 1932 Dr. Steggerda was in the field during March and April. Dr. Davenport, Director of the Department of Genetics, came to Yucatan with Dr. Steggerda to make acquaintance with the field and to gauge its possibilities for genetic research. It is one of the greatest advantages of the Chichen Itzá headquarters that it permits members of the resident staff to have contact with other scientists and to see their own problems from fresh points of view.

#### ETHNOLOGICAL RESEARCH, BY ROBERT REDFIELD<sup>1</sup>

The studies we have begun of the contemporary people of Yucatan are guided by two primary assumptions. One assumption is that although scientific interest in the Peninsula had its beginning in connection with the ancient Maya culture, and although it is certain that study of the present-day Maya will throw light on the Indians of the times before the Conquest, nevertheless, the ultimate aims of science are more likely to be served if the student describes what is actually before him. If a student of society should report only what is apparently aboriginal in the contemporary culture of Yucatan, he would be like one charged to study and describe the structural mechanics of a building, who would ignore everything in the house but heirlooms brought over on the Mayflower. To learn the rules by which a thing works, you have to study the thing as it works before your eyes. The Maya elements in the contemporary culture of Yucatan are now thoroughly integrated with elements of European or modern American origin. The life in the villages is tied up with institutions that have their roots in the capital city, and with an economic system that includes the whole world.

The other assumption is to the effect that a description of contemporary Yucatan can be more than a mere depiction of a static condition, and that by virtue of the fact that the area, geographically homogeneous and racially

<sup>1</sup> Dr. Redfield's work on the Maya is made possible by the cooperation of the Department of Anthropology of University of Chicago, which grants him, through courtesy of its Chairman, Dr. Fay-Cooper Cole, periodical leave to take the field.



simple, contains within it communities ranging in complexity from the family or tribal group of primitive Indians to the large urban aggregate which is Merida, the capital, the description can, in effect, describe a process. If studies be made of communities along this range of sophistication, and these studies be made comparable, the comparison should constitute a summary account of how man gets to be civilized, or, what is the same thing, urbanized. Instead of making a picture, we will make a moving picture. It will show some of the changes that take place as the isolated community, economically independent and non-literate, gives way to the complex and heterogeneous city.

The ultimate importance of this description of process will result, we hope, from the interest we have in making the description a little more than the account of a unique series of events, more than a mere inventory of ethnographic fact. We should like it to emphasize the resemblances and the repetitions of the cultural process. We want it to group and to classify. We want to see what there is that is alike in the various instances of becoming civilized, both as among communities within the Peninsula, and also as one compares the situation in Yucatan with similar situations elsewhere. We shall be describing one case, but always with an eye out for other cases of the civilization process in other places. The moving picture will, we think, have a certain flavor of familiarity to those who have seen the theme, folk-to-city, employed on some other stage. Our studies of this special concrete situation are made orderly and systematic by centering our attention upon the contrast and the transition between two ideal types of societies: the folk culture, non-literate, unsophisticated, with a simple division of labor and homogeneous and relatively immobile customs involving many sacred sanctions; and, on the other hand, the city civilization, literate, sophisticated, with a complex division of labor, heterogeneous moral and religious customs and a predominance of impersonal contacts and secular institutions. In this way a regional survey can become, in effect, a scientific hypothesis.

We have begun this task at the two ends, by initiating studies of Maya villages and by investigating the Yucatecan society as a whole, with special reference to the one large city. In 1930-31 Alfonso Villa and I studied Chan Kom, a Maya village in the Valladolid region, and Mrs. Redfield and I began the study of Merida. During the year 1932 Dr. Asael T. Hansen and Mrs. Hansen carried forward the work in Merida. They concentrated special attention upon the *barrio* of Santa Ana, a part of Merida that has undergone great changes due to the growth of the urban area and the introduction of recent elements of outside civilization. These changes have not gone on evenly, and have resulted in a condition of extreme diversity. A study of this *barrio* thus reveals the range of culture and social classes in the city. The old aristocracy are present, many of whom have travelled and studied in Europe and the United States, and who participate in the currents of world civilization. Two streets in Santa Ana are occupied by middle and upper middle-class people, and in the rest of the *barrio* live lower middle-class and lower-class people. Here persist many elements of folk culture, such as the thatched hut and the *mestizo* costume. The herb doctor competes with the modern physician, and black magic is much feared. But elements of urban civilization are pushing in and displacing the folk culture. No one ever builds a new house of thatch; very few children dress in the *mestizo* costume; and black magic is becoming a superstition.



Dr. Hansen made an intensive study of one block on one of the middle-class streets. Here his material is so complete that he can compare cultural features of the various households in tabular form. At the same time his less exact materials, derived from personal association with people in many walks of life, are being classified according to a scheme of presentation that is guided by the problem central to the various studies: the transition from folk culture to city civilization. It is Dr. Hansen's plan to spend the second half of 1932 living in and studying another Merida area in which there is a higher degree of homogeneity. In this area dwell lower-class people who have not taken on so much of the urban civilization. Such an area will contrast strongly with the block already studied in Santa Ana. By judicious sampling of the metropolitan region, it is believed that we can fairly represent the situation in the city.

While Dr. Hansen and his wife have carried on the field work, Mrs. Redfield and I have been working on the project during the summer of 1932. Mrs. Redfield has undertaken the study of the Merida press, daily, weekly and monthly. From these periodicals she clips revelant materials, and classifies them according to the same scheme which the Hansens are using in the field. In this way it will become possible to combine two different sources of information: the materials gathered in field work, and published documents.

I have been employed, during the summer, in a study of the materials collected last year by Villa and me in Chan Kom, and in writing them into an ethnographic monograph descriptive of that community and its culture. I plan to take this manuscript back to Yucatan next year, and by going over it in the field, substantially to extend its contents and to check its accuracy. The preparation of it has made it possible for me to see the weaknesses in the work already done. As it now stands the monograph is of value as a study of a peasant community. But the worth of this particular study will be increased as we make similar studies of other villages at different levels of economic and cultural development. Writing up these notes has helped to guide the other studies to comparable forms.

The next village study proposed is of a Maya settlement in Quintana Roo.<sup>1</sup> This work will be begun in December 1932, by Alfonso Villa, who, from his years of service, first as a rural teacher and then as an ethnological assistant, has already a knowledge of Maya customs and language. In preparation for intensive work, Villa made a five weeks' trip of ethnological reconnaissance in little known parts of the Territory. He traversed most of the region north of and including Petcacab, west to and including Xiutil (just east of Lake Chichancanab), and south of a line drawn from Valladolid to the south end of Cozumel Island. He visited twenty-eight Maya settlements. Concerning this part of the Maya territory we have almost no ethnological information. Villa prepared a satisfactory map of the villages here, and made a good photographic and journal record. The villages are grouped into three political-religious divisions, each under the dominance of a native priest and a native chief, who are resident in one of three sacred settlements, each guarding a shrine in which is a cross that utters or writes oracular pronouncements and instructions. Villa visited one of these shrines, and determined the allegiance of each of the twenty-eight villages to one or another of the shrines. The central of these three

<sup>1</sup> The Territory of Quintana Roo, as a political division, was abolished January 1, 1932, when the northern half was made part of the State of Yucatan, and the southern half was made part of Campeche.

groups of villages is least affected by schools and other recent influences, and Villa selected one of the villages of this group for future study.

Although most of his time was of necessity spent in travelling through the bush from one settlement to another, Villa collected enough casual ethnological information to suggest the existence of many problems for further investigation. It appears almost certain that the extended domestic family is much more important in the Territory than it is in Chan Kom, where we find that institution largely superseded by the small individual parental family. It is also probable that in some cases in Quintana Roo the young married man works for his father-in-law to earn his bride. Villa also received accounts of the New Fire (Tumbul Kak) ceremony held on Holy Saturday, when the fires are extinguished in all the houses and are re-lighted from a new fire, ceremonially kindled, at an hour announced from a consultation of the stars, by means of a fire drill operated by certain personages known as Hot Hands (Choco Cab). Here we apparently have another interesting instance of the syncretism of pagan and Catholic custom.

#### LINGUISTIC INVESTIGATIONS, BY MANUEL J. ANDRADE<sup>1</sup>

During the period under consideration no work was done in the field. It was thought advisable to devote this time to the study of the material collected in the two previous years, and to make preparations for future investigations. The usual routine of the morphological analysis of the hundreds of pages of texts and grammatical material, besides the various other procedures commonly employed in linguistic analysis, are the tasks which must be undertaken before a detailed account of the Maya language and its two closely related dialects, Mopan and Lacandon, can be given.

Part of the material recorded on dictaphone cylinders is now being analyzed with the aid of an oscillograph in order to obtain accurate measurements of certain tonal and duration factors which play an important part in the phonetic structure of the Maya language. Various technical difficulties had to be overcome before it was possible to obtain photographs of the sound waves recorded on the wax cylinders. Thanks to the expert collaboration of Mr. S. N. Treviño of the phonetics laboratory of the University of Chicago, the results are quite satisfactory. They will be the subject of a special article on the melodic patterns of Maya words.

Part of the preparations for future field work consist of the compilation of a linguistic questionnaire to be used in the study of all the languages and dialects of the Maya stock. A handicap with which students of comparative linguistics have frequently to contend is the omission of data in the material compared, which, in the course of the research, turn out to be the key to the solution of particular problems. Naturally, such gaps are more likely to occur when the information has been collected by different investigators. It may thus happen that it is not possible to trace the history, or map the distribution of a word connected with an important cultural fact because it is not found in the texts or vocabularies recorded in two or more of the languages compared. It seems possible to obviate such difficulties to a considerable extent by using a uniform set of questions for all the languages studied, in addition to the usual methods of collecting linguistic material. This questionnaire, to judge by the data thus far compiled, will consist of over 4000 words comprising the names of the animals, plants, artifacts and other items of culture and physical environment which may be expected to

<sup>1</sup> Dr. Andrade's research is a joint undertaking of the Department of Anthropology of University of Chicago and Carnegie Institution of Washington.

be common to all the Maya-speaking peoples. It will also include the current vocabulary essential in all human communication. Another portion of the questionnaire will be devoted to grammatical phenomena, the questions being designed to discover in each language the existence or absence of characteristic features observed in the related languages and dialects previously studied.

Other preparations are the selection and adaptation of apparatus to record and analyze speech sounds in the field. The collection of phonic material serves various important purposes. In the first place, it is desirable to have permanent phonographic records of the languages included in our project. The archeologist and the student of material culture provide for future inquiry by storing in museums the products of the arts and industries of extinct civilizations as well as those of living cultures. The linguist, likewise, preserves his texts, a documentary evidence of the more important aspects of language, which facilitates future research by himself and others. However, his permanent records would be even more complete than those of the other students of culture were he able to file faithful reproductions of the phonic aspects of language. Until recently, the phonographic records which could be made in the field were very unsatisfactory for scientific purposes, and their permanency as material accessible to other investigators involves considerable expenditure of time and money. It is now possible to use in the field an electric apparatus to record speech on aluminum discs. Several copies can be made from one of these discs at a negligible cost, and it is claimed that each one of the aluminum copies can be played over two thousand times without any perceptible wearing. The Carnegie Institution has had such an apparatus constructed under specifications calculated to meet the requirements of our work. After a period of testing, it is now being improved under expert advice to provide against various difficulties encountered by the traveller in the less accessible parts of the Maya area. The apparatus reproduces, with more accuracy than has been possible heretofore, most of the physical aspects of sound which are of interest to the linguist. An archive of such records will doubtless be welcomed by students of aboriginal languages, not to mention others interested in problems of general linguistics.

Apart from its services for the above purposes, the writer believes that the use of such a machine will mark a distinct improvement in the technique of recording languages. As this is not the proper place to enumerate all its technical uses, it may suffice to mention one. A great deal of artificiality is introduced in the process of recording connected discourse in an unknown language. The informant must conform to the exigencies of the investigator by dictating at an unaccustomed slow speed, enunciating clearly, stopping between the word groups of a given sentence, if it happens to be long, frequently repeating some of the words before the sentence is completed, in order to facilitate phonetic observations, besides other disturbing factors familiar to all field workers. Many informants who can give valuable ethnologic information in their native tongue are not available to the investigator because they can not adapt themselves to the unnatural conditions of dictation. If the informant is adaptable, the recorder may find it difficult to make various observations which may be of importance in some languages, as for example: the syntactic function performed by melodic aspects of the sentence, which may be evident only when speaking at a natural speed; word grouping; phonetic subordination, which may occasionally decide whether a given morpheme is a proclitic or a prefix; and other points



which may be negligible in some languages, but are always of interest to linguistic science in general. Such aspects of language can be more accurately and conveniently studied from the aluminum records mentioned above. It is true that the informant must at first become accustomed to speaking before a microphone, but this is rather simple in unsophisticated environments, especially if the native faces a group of his own people while recording. At least, such has been our experience in the use of the dictaphone in previous field work.

Another preparation which is now in progress is the selection of reliable instruments for the analysis of speech sounds, which can be adapted to field work. In recent times the physicist and the experimental phonetician have made considerable improvements in such mechanical devices, but practically all of these have been designed for the laboratory. Our task is to select the most essential of these modern inventions and to make such alterations as will facilitate their use where the conveniences of the laboratory are not available. Very little use of physical apparatus has been made in the past in the study of aboriginal languages. Most of the investigators have depended entirely on their auditory ability. Formerly this was due in part to the imperfection of the instruments that were at our disposal, and more recently, when such highly refined instruments as the oscillograph have been constructed, it is due, also, to the fact that they can not be used in the field. But besides these handicaps, there are also theoretical objections. Some investigators contend that speech sounds are essentially psychologic facts, and hence observations on their physical aspects are irrelevant for linguistic purposes. In such extensive investigations as have been planned in our Maya linguistic project, it would not be advisable to neglect any aspect of the subject on theoretical considerations. The precise determination of the physical aspects of speech in no way obstructs a psychological or purely linguistic interpretation. It may be argued further that, since it is the goal of every science to eliminate the personal equation to the greatest extent possible, it is desirable to avail ourselves of mechanical devices for the description of linguistic sounds, to the extent that the measurements thus obtained may be pertinent and reliable.

#### SUMMARY OF THE MAYA SURVEY

Archeologically, this has been perhaps the most productive year of the Institution's nearly two decades in the Middle American field. At Chichen Itzá, the work at the Mercado has transformed a meaningless heap of tumbled stone into a beautiful and understandable example of Nahuatl-Maya architecture at its apogee; the investigation of the Monjas inaugurates a study which will surely throw much light on the earlier, purely Maya, period. The Calakmul expedition brought knowledge of a very large, strategically located and hieroglyphically very fully documented Old Empire city in a region whose further exploration promises much of vital interest. Uaxactun yielded a number of richly stocked tombs; the excavation of the "Palace" throws light on an important type of building which, in the Peten, has not hitherto been examined; but probably most valuable of all was the discovery of the prolific and well-stratified rubbish deposit, the abundant sherd material from which will add greatly to our knowledge of Old Empire ceramics. The architectural-ceramic survey demonstrated, in northern Yucatan, the soundness of its methods and resulted in collection of data to found a truly scientific study of the archeology of that area. In



Guatemala, Dr. Lothrop's work constituted a start at unravelling the complex problems of the Highlands.

The year's accumulation of data has been unusually great. The difficulty of making these data promptly and fully available remains acute. The published report, presenting both the facts and the investigator's deductions therefrom, is the end-product of all research. In archeology, however, materials pile up so rapidly, and their study is so long and so arduous a process, that writing proceeds very slowly. The result is that no member of the Section's archeological staff, save Mr. Ricketson, is fully abreast, in the matter of publication, of his field work; some, indeed, are several years behind. It would seem obvious that field activity should, in each case, stop until the individual concerned has caught up. But many practical considerations, contracts with governments, the holding together of digging and transportation organizations, urge continuance. Very anxious thought is being given to this problem.

A number of non-archeological researches have gone forward, with Guatemala the principal center of activity. There, geographical reconnaissances have been begun, medical studies inaugurated, as well as volcanological observations by Dr. Zies of the Institution's Geophysical Laboratory. A party from Duke University and the University of Michigan is, during the present summer, at work upon the biology of the inland waters of Yucatan; their results will be reported in the next Year Book. The ethnology of Yucatan continues under study by Dr. Redfield's group; Dr. Steggerda made his annual visit to Chichen Itzá for anthropometric purposes. Mr. Scholes is in Spain collecting archive materials bearing on the history of the Maya; Mr. Roys is translating and annotating the historical sources in the Maya idiom. All these projects are making satisfactory progress. There remain, however, a number of really essential additions to the list. The need for a topographic survey of the Guatemala Highlands has already been stressed. The geographic work in that region should also be supplemented by specific attention to geological and volcanological problems. The geology of the Peten and of northern Yucatan must eventually be carefully investigated. Nothing at all has as yet been done upon the basic environmental factor of climate. Agronomy clamors for attention. The biological field has hardly been scratched.

#### SOUTHWESTERN RESEARCH

In the Section's second field of archeological activity, the southwestern part of the United States, Mr. E. H. Morris carried on extensive and profitable excavations. To understand the purpose of this work and to appreciate the significance of what was found, it is necessary to recall the fact that in the Southwest a relatively high aboriginal culture, based on agriculture, grew up, so to speak, *in situ*. Every step in the long, slow development from nomadic savagery to a condition closely bordering on civilization took place, with little or no outside contact, within the borders of the Southwest. And, thanks to abundance of remains and to the arid climate which has preserved them so perfectly, the story of that development can be worked out with a degree of accuracy and with a wealth of detail not

to be equalled in any other part of the world, with the possible exception of Peru. The major outlines of Southwestern history are now known; and, thanks to the Douglass tree-ring method, its later stages can actually be dated in terms of our chronology.

Because of the unique materials available therein for students of the growth of culture, the Southwest is a field, *par excellence*, for intensive and meticulous investigation. Mr. Morris's work during the summer of 1931 was planned and carried out with this in mind. His objective was a definite one, to discover and excavate a pure Basket Maker III cave.

The Basket Maker III people were the direct descendants of an earlier semi-nomadic, partly agricultural population (Basket Maker II). They were the great developers of the northern wing, at least, of Southwestern culture. They became sedentary, fully agricultural, built permanent houses, began the manufacture of pottery, and, in a word, laid the foundations for the subsequent achievements of the Pueblos. Their general contribution is known, but many very important aspects of their life and many details of the growth of their industries still await understanding. The reason for this is that well preserved Basket Maker III remains are only to be found in caves. Caves, in the Southwest, being very attractive dwelling places, were occupied almost continuously from the time man first came into the region until they were finally abandoned by the Pueblos. Hence one finds, upon excavation, a superposition of remains that enables one to work out the general succession of cultures; but one also finds, in these long-used shelters, that the deposits have been so disturbed, so churned, by the digging of graves, the clearing of areas for house-foundations and otherwise, that it is next to impossible to obtain an absolutely uncontaminated sample of the remains of any given period. But such a sample, particularly from the all-important Basket Maker III period, it is essential to have. For years Mr. Morris has, therefore, been looking for a cave which had been occupied only by this people. And, finally, he found one, a huge shelter at the head of a small deep side-canyon in the Red Rock country at the eastern foot of the Chuska mountains in north-eastern Arizona. The summer of 1931 was devoted to its excavation. Mr. Morris's report follows:

"The field work in the Southwest was confined to an area about five miles square, at the extreme western edge of the Red Rock district of northeastern Arizona. The principal site explored was Broken Flute cave, situated at the head of a north branch of Atahonez canyon. This shelter is horseshoe-shaped with open side to the south, approximately 800 feet long and 60 in greatest breadth. Toward one end of the cave, there was originally a deep pocket of considerable extent. Charcoal in lumps of appreciable size is so prevalent down to the very lowest strata, at a depth of 13 feet, which fill this pocket, that it seems unquestionable that the carbon resulted from fires made by man. Since the entire mass had been wet time after time, thereby decaying such perishable objects as might have been present, and since the components in imperishable media of Southwestern material culture prior to the advent of pottery are very few in quantity, the absence of flint and bone in the few cubic yards of the charcoal impregnated strata which were worked over by no means disproves the presence of man during the period of deposition. These strata, lying entirely beneath the Basket Maker III

level of occupation, would seem to offer the possibility of proving human frequentation of the region in times ancient enough to be measured by thousands rather than hundreds of years. With the exception of one cross-section trench, the beds were left undisturbed with the hope that at some future time they would be adequately dissected. Aside from this deposit and minor areas which have been wet, or are deeply covered with rock fall, the entire cave was excavated, mapped in detail, and thoroughly photographed. The structures cleared comprise 15 large chambers and 65 storage cists. In many of the enclosures of both types, and over all areas which were not occupied, there was a blanket of refuse from a few inches to several feet in thickness. This largest of all the dry shelters in the region yielded prolifically, both of information and specimens. In addition to Broken Flute cave, 16 smaller ones, distributed along Atahonez canyon and Black Horse creek, were excavated wholly or in part, as the nature of their contents dictated. Some digging also was done in the small open sites which are numerous on the ridges and knolls which fringe the narrow valleys composing the terrain. Aside from notes, maps, and photographs, there were gathered some 2000 objects, constituting 1421 catalogue entries. The most striking of the specimens are six long braided sashes of animal hair, two white, two black and white, and two brown. The white wool has been identified as dog hair, but the black and brown have not been positively accounted for. Less beautiful, but fully as important as the sashes, is a series of unfired clay vessels in a variety of shapes and sizes. Only fragments of such containers have been previously exhumed. Other outstanding features of the collection are two wooden flutes decorated with feathers, and several caches of beads and ornaments.

"The season's activities reveal that the Red Rock valley was inhabited from beginning to end of aboriginal occupation of the San Juan area, of which the valley is a part. Culturally speaking, this is from Basket Maker II to the end of Pueblo III. The caves, however, were for the most part avoided by the latter peoples. The sparse inhabitants of the Basket Maker II period left some evidence of their presence in the dry shelters. Throughout the next culture period, namely Basket Maker III, the caves fairly teemed with population, and there was left in them a full representation of the material arts of the age. The light that it has thrown upon this very important stage in the development of Southwestern culture is the chief contribution resulting from the field work of 1931, for it will enable not only a thorough description of Basket Maker III culture, but will also make possible the identification of specimens of Basket Maker III age present in the large mixed collections from other localities. Owing to the dryness of the caves, most of the timber used in house construction was excellently preserved, whether in natural condition or carbonized by conflagration. In consequence, more than 300 sections of the varieties of wood suitable for the purpose were sent to Dr. A. E. Douglass for study in connection with his tree-ring dating of southwestern ruins. There is no doubt that this large series, together with material of similar age already in his hands from other localities, will establish a definite time count spanning the entire length of the Basket Maker III period. While this may not connect with the nether limit of Dr. Douglass's present historic series which reaches back to 740 A.D., further excavation will eventually provide timbers to bridge the gap, thus extending the positive year for year chronology for the aboriginal cultures of the northern Southwest very near to, if not beyond, the beginning of the Christian era."



## SECTION OF UNITED STATES HISTORY

The work in the Section of United States History has gone steadily forward throughout the year. At the close of the last fiscal year three volumes were going through the press and were soon to be published. These volumes have since been brought out—volume V of Dr. Burnett's *Letters of Members of the Continental Congress*, extending through the year 1780 and to February 28, 1781, was published in October; volume II of Miss Donnan's *Documents illustrative of the History of the Slave Trade to America*, dealing with the trade in the Eighteenth Century, was brought out in November; and volume I of Dr. Leland's *Guide to Materials for American History in the Libraries and Archives of Paris* appeared in May. The following volumes have also been put into the press and are at this time in various stages of completion: In December volume III of Mrs. Catterall's *Judicial Cases concerning American Slavery and the Negro* was sent to the printers and in April, when Mrs. Catterall sailed for Europe, the galley-proof had all been read and a considerable portion of the book was in page-proof. At the close of the year reported upon, the index to this volume, which is being prepared by Mr. David M. Matteson, is nearing completion. The next manuscript to be sent to the press was volume III of Miss Donnan's series on the slave trade. At the time when this series was first planned it was expected that volume III should cover the trade with the individual colonies, closing the series. But during the time intervening since the publication of volume I considerable additional material had been found, much of which could not well be disregarded, and it was therefore decided to extend the series to a fourth volume, which should cover the Southern Colonies. Volume III deals with the trade in New England and the Middle Colonies, and the closing of the year finds it in large part in galley-proof and the work upon it going rapidly forward. At the end of June the manuscript for volume VI of Dr. Burnett's series, extending from March 1, 1781, to the end of 1782, was in the printers' hands and work upon it had been commenced. The proofs of the *Atlas of the Historical Geography of the United States*, which is being published jointly with the American Geographical Society, have all been read by Dr. Paullin and Miss Pierce. The annual List of Doctoral Dissertations in History was brought out. Further progress is reported as having been made upon the index to the *Calendar of Manuscripts relating to the History of the Mississippi Valley*, which is in the hands of Mr. Matteson. There has been considerable but necessary delay in the preparation of this index, but it is hoped that Mr. Matteson's work will be completed during the coming year and that the index will be ready for distribution soon thereafter. In several instances it has been possible to extend privileges to research workers in history by affording them the use of manuscript materials for Guides which are awaiting future publication.

Miss Cornelia M. Pierce, secretary of the Section, has been engaged in the manifold editorial tasks involved in preparation for and seeing through the press the volumes mentioned above. Dr. Waldo G. Leland, in spite of pressing duties as Permanent Secretary of the American Council of Learned Societies, has found time to keep in close touch with the activities of the Section. His advice has been sought upon many important problems.



At the time when the latest annual report was issued, volume V of Dr. E. C. Burnett's *Letters of Members of the Continental Congress* (Jan. 1, 1780–Feb. 28, 1781) was just off the press. In the autumn of 1931 it was distributed. Volume VI of the *Letters*, which brings these materials to the end of 1782, has since been completed and was sent to press in June. The preparation of this volume has mainly engaged Dr. Burnett during the past year, although one or two lesser undertakings have been interjected. One of these was an article to which was given the title "Who was the First President of the United States?" and put forth by the Division of Publications in May as a "release"; another was a paper entitled "George Washington and Committees at Headquarters," read before a special meeting of the American Historical Association held in the Library of Congress May 7, as a feature of the George Washington Bicentennial Celebration.

With regard to the first of these papers it may appropriately be remarked that in view of a contention given wide publicity during the present year, that John Hanson rather than George Washington was the first President of the United States, it seemed that the Institution might perform an exceedingly useful and patriotic service in this bicentennial year by despatching the truth in pursuit of this error; for the contention, though based entirely on erroneous interpretations and conclusions, was winning no small degree of acceptance. It is hoped that the wide and efficient dissemination of the article by the Division of Publications will have the desired result. At the moment of writing it is known that at least one foreign publication, the *Cork Examiner*, has printed the article entire. It has also been reprinted in the June issue of the *Carnegie Magazine*.

Dr. Burnett has continued the preparation of American Notes for the American Historical Review, as he has also continued, to a minor extent, the preparation of biographical sketches for the Dictionary of American Biography. The lecture on "The Continental Congress and the Achievement of National Unity," which was delivered in the assembly hall of the Administration Building in March of last year, has been twice repeated during the present year, once before the Catholic University of America and again before the Cosmos Club.

During the past year Dr. Paullin has been chiefly employed on the *Atlas of the Historical Geography of the United States*. The correction of the final plate-proofs of the maps and the page-proof of the text, including the preface and introduction, recently written, has been completed and the publication of the *Atlas*, within a few weeks, is announced. A selected list of maps illustrative of the contents of the *Atlas* and more particularly of the expansion of the United States was exhibited by means of the balopticon at the annual exhibition of the Institution in December. The showing of the slides was accompanied by an explanatory talk by Dr. Paullin. About the same time a somewhat similar exhibition, in which some of the same materials were used, was made before the Association of American Geographers at Ypsilanti, Michigan, by Dr. John K. Wright, librarian of the American Geographical Society.

The preparation for publication of the manuscripts for *European treaties bearing on the History of the United States, 1715–1815*, has been continued with the aid of Miss Florence Spofford, expert copyist, and of Dr. James A.

Robertson and Mr. C. K. Jones, translators. With a possible exception or two, all the necessary manuscripts have been obtained from foreign archives and nine-tenths of the copying has been completed.

A brief account of Dr. Paullin's investigation of eminent Americans based on the biographical sketches in the Dictionary of American Biography was given in the annual report of the Division for 1931, pages 153-154. This year the materials of the Dictionary were studied in order to select the categories for classifying the available information and to make the most convenient arrangement of the items under each category. On the completion of this study, volume I was analyzed and in the light of the information thus obtained the preliminary plan was much improved. In May Dr. Paullin visited Cold Spring Harbor for conference with Dr. Charles B. Davenport, Director of the Department of Genetics, receiving from him many helpful suggestions, especially in respect to the influence of inheritance, the inter-relationships of noted families, and the classification of human traits. Dr. Davenport expressed a desire to cooperate by furnishing any needed information from the abundant resources of the Eugenic Record Office. Some of the precise methods of that office were found applicable to the investigation of eminent Americans. Dr. Paullin has continued to act in an advisory capacity to the Dictionary of American Biography, and as trustee and treasurer of the Naval Historical Foundation.

The work of collecting and annotating copy for Dr. Leo F. Stock's *Parliamentary Proceedings and Debates of the British Parliaments respecting North America* has made the usual progress during the past year. The text and notes for the forthcoming volume IV have been particularly enriched by much material relating to Anglo-Spanish relations in the West Indies, supplied from the photostatic copies of the Manuscripts of the House of Lords in the Library of Congress. During the year the work of transcribing the stenographic reports of the Egerton manuscript, mentioned in last year's report, was practically completed by Mrs. Charles Eliot, to whom the Division and the editor are again indebted for her interest and labors in this difficult task. The results of this phase of the work have shown the desirability of testing at some future time the remainder of this stenographic report.

Aside from his parliamentary work Dr. Stock has again acted as chairman of the Committee on Publications of the American Historical Association, and has served on that association's committees of Documentary Publications of the U. S. Government and of the special meeting held to celebrate the bicentennial of the birth of George Washington. He was elected a member of the Executive Council of the American Catholic Historical Association; he continued as co-editor of the *Catholic Historical Review*; contributed monthly bibliographical notes to the *Historical Outlook*; acted as American adviser to Rhodes House Library, Oxford, on recent American historical publications; and lectured at Cliff Haven, New York, St. Joseph's College, Emmitsburg, Maryland, St. Mary's Seminary, Baltimore, Maryland, and before the Cosmopolitan Club, Washington, D. C. He represented the Institution at the centennial exercises of Gettysburg College, Pennsylvania.

Mrs. Helen T. Catterall, in addition to reading the proof of volume III of *Judicial Cases concerning American Slavery and the Negro*, has finished the excerpts from the Texas reports, those from the Pennsylvania reports have been brought down to 1855, and the introductions for those states have been written.

The question of slavery in Texas continued in a state of uncertainty until the formation of the Constitution of the Texas Republic. Notwithstanding the provision of the constitution of Coahuila and Texas, adopted in 1827, that "no one shall be born a slave, in the State, and after six months, the introduction of slaves, under any pretext, shall not be permitted," slavery never ceased to exist in Texas, *de facto* if not *de jure*. The date of the abolition of slavery in Texas was fixed, by the "Emancipation Proclamation Cases" of 1868, at June 19, 1865, when General Gordon Granger by his order informed the people of Texas that all slaves were free.

A great number of Pennsylvania cases have to do with the construction of the act of 1780 for the gradual abolition of slavery (together with the supplementary acts of 1782 and of 1788), and with attempts to obstruct the enforcement of the fugitive slave laws of 1793 and 1850. The activity of the Pennsylvania society for promoting the abolition of slavery is evident, beginning with the first case quoted. Justice Baldwin declared in 1833 that the society had "pursued their legitimate objects with untiring zeal." "To protect or rescue runaway slaves" was "no part of . . . (their) design . . . (but) equally repugnant to the feelings and practice of the members, as it would be to their charter." He might have revised his statement twenty years later when Mr. David Paul Brown, "being . . . it was supposed, employed by certain societies in Philadelphia, known as 'Friends of Humanity,' 'Abolitionists,' etc.," was forbidden by the court to interfere in the *habeas corpus* proceedings for the discharge of three deputy marshals who had assaulted a fugitive slave in attempting to arrest him. Two years thereafter the high-handed conduct of Passmore Williamson, secretary of the active committee of the old Pennsylvania Anti-Slavery Society, landed him in prison.

Mr. France V. Scholes, who is engaged in researches upon Latin-American history, with special emphasis upon the history of Yucatan from the time of the Conquest until the present, devoted the period under review to completing an earlier investigation of the relations between church and state during the Spanish régime in New Mexico. He also continued a preliminary check, begun last year, of the printed sources for Yucatecan history, working principally in the library of Harvard University. Mr. Scholes has now gone to Spain for an extended stay, where he will search the archives at Seville and elsewhere for documentary materials upon Yucatan. He will also visit France, England, and Italy. Assisting Mr. Scholes, on a half-time basis by arrangement with Harvard University, is Mr. Robert S. Chamberlain. Mr. Scholes reports that he has found the Archives of the Indies at Seville enormously rich in papers bearing upon all periods. These he is reproducing, by photostat and Leica photography, to bring to the United States for study.

Mr. Ralph L. Roys has undertaken a study of the *Crónica de Oxkutzcab*, also called the Xiu Chronicle, which is the book of *probanzas*, or proofs of



nobility, of the Xiu family of Oxkutzcab. During the entire colonial period the descendants of certain ruling Maya Indian families in Yucatan were considered to be *hidalgos* and "native lords" and enjoyed many privileges. They were exempt from tribute, and the local community was compelled to cultivate their lands, garner their crops, rebuild their homes when necessary and supply them with domestic service. Such a procedure kept the most influential native families loyal to the Spanish government, and the policy was a notably successful one.

Believed to have been of Mexican origin, the Xius were noted for their political shrewdness prior to the Spanish conquest, and in their papers we find much evidence of the same judicious opportunism in their relations with the Spanish authorities and missionaries.

The documents consist of Maya petitions from the heads of the family confirmed by the Defender of the Natives, Spanish decrees by the Governors, often accompanied by Maya translations, and a confirmation of the latter in Maya signed by the local officials. There is a Xiu family tree beginning five or six generations before the Spanish conquest, and the map and Maya minutes of the famous Mani land-convention of 1557, which contain much ethnographical material hitherto unpublished. On the back of an interesting personal letter is a Maya chronicle of the time of the Conquest, stated by its writer to have been transcribed from a hieroglyphic codex. This contains data which make it the basis of one of the important correlations of Maya and Christian chronology. We also find a wealth of detailed information as to the manner in which Maya local institutions were adapted to the needs of the Spanish colonial administration.

The collection has great linguistic value, as it presents a series of dated Maya texts covering the greater part of the colonial period. Here we may trace the changes which occurred in the language at a time when a certain amount of European culture was being introduced into Yucatan and combined with or superimposed upon the native customs and beliefs. The series should also constitute a standard by which we may approximately determine the age of other Maya texts which bear no date.

Mr. Roys has completed the transcription of all the documents of this collection, many of which are faded, torn, or badly written, and the material has been translated and annotated down to the year 1738. The series ends in 1817. The publication of the *Crónica* will contain, by way of introduction, a history of the Xiu family compiled from other sources and something of Spanish ideas regarding the status of "native lords" in New Spain. An appendix will present other versions and one other map of the Mani land-convention; another will discuss the meaning and possible origin of the Maya family names occurring in these papers.



SECTION OF HISTORY OF SCIENCE AND  
ALLIED INVESTIGATIONSHISTORY OF SCIENCE, BY DR. GEORGE SARTON<sup>1</sup>

Dr. George Sarton left Cambridge on July 26, 1931, for a much needed vacation and for a year's study in the East. The purpose of his journey was twofold: (1) to obtain a deeper and more fluent knowledge of Arabic, and to make a comparative study of the Arabic language as actually written and spoken in various countries; (2) to visit the countries of the Mediterranean world, especially the Muslim and Arabic ones, and those which had been subjected to Muslim influences in the past (as Greece, Sicily and Spain).

These two purposes were somewhat conflicting, because the second one implied considerable traveling and—considering the length of the itineraries and the shortness of time—frequent changes of base; while the first could only be attained if Dr. Sarton stayed long enough in any one place. Moreover, for his Arabic studies, he needed a larger amount of books than could conveniently be carried in his luggage.

It was necessary to compromise. A relatively long stay (over five months) was made in Beirut (Lebanon, Syria) where most of his time was devoted to the study of classical Arabic and of the Syrian dialect. This period was rendered at once very profitable and very pleasant, thanks to the hospitality and the kind cooperation of the American University, the courtesy and helpfulness of whose authorities is deeply appreciated. He made a shorter stay in Tlemcen, an ancient Islamic capital, situated in the hills near the Moroccan border. This enabled him to obtain a definite idea of Western Islam and of Algerian and Moroccan Arabic.

In order to accomplish his second purpose of obtaining a broader perspective, he travelled as extensively as was possible in so short a time in Northern and Southern Syria, chiefly in the Lebanon; also in Palestine, and in Transjordan, which he traversed almost completely from the capital, Amman (the ancient Philadelphia), down to Macan and Petra, along the Pilgrim road to Mecca, and as far as the boundary of Arabia.

Dr. Sarton left Beirut in the beginning of May, and proceeded to the island of Rhodes and to Istanbul, then to Athens, to Rome, Naples, Palermo, and to Tunis. He crossed North Africa to Tlemcen, and, at the close of the period under review, was on the way to Morocco, where he hoped to continue his study of Arabic in Fez, and if the summer heat did not prove unbearable, to see various other parts of Morocco, both French and Spanish, before visiting the Muslim remains of Spain. After short stays in Paris, Brussels, and London, where he will meet a number of European Orientalists and historians of science, he will return to America in September.

It is difficult for Dr. Sarton to draw final conclusions at this time, for he has gathered so many facts and impressions during his travels that it will require years of collateral reading, study, and meditation to make full use of his accumulated experience. However, two important conclusions can already be formulated at the present time:

1. The essential unity of the Arabic language—past and present—in all the countries visited by him. That unity is at least as great as that of any

<sup>1</sup> Fourteenth annual report, for period extending from July 1, 1931, to June 30, 1932 (previous reports in Year Books Nos. 18-29; the twelfth also in *Isis*, 15, 170-171, the thirteenth in *Isis*, 17, 209-217).

other language under similar conditions (particularly the lack of independence and political unity). That unity is largely accounted for by the religious (Muslim) unity of the vast majority of Arabic-speaking people.

2. The essential unity of the Mediterranean world. The Mediterranean Sea favored communications far more than it hindered them, and caused the existence of homogeneous culture along its shores, North and South, East and West. This was promoted by the imperialism of a number of peoples: Egyptians, Phœnicians (Carthaginians), Ægeans, Greeks, Romans, Byzantines, Muslims, Turks, and finally the various Latin and other European peoples having settlements and "interests" in that part of the world. This is of great importance, because the Mediterranean basin was really the cradle of European and American culture.

The work done by members of this Section during the year 1931-32 may be summarized as follows:

1. *Introduction to the History and Philosophy of Science*—The second volume of Dr. Sarton's *Introduction*, From Rabbi ben Ezra to Roger Bacon (pages 1 to xxxv and 1 to 1251) was published for the Institution by The Williams and Wilkins Company of Baltimore, in November 1931. It consists of two parts, devoted to the Twelfth and Thirteenth Centuries, respectively. The general index to the second volume (108 pages) was compiled, under the direction of Dr. Sarton, by Miss Frances Siegel (Radcliffe '31); after the departure of Dr. Sarton for Europe and the near East, Dr. Pogo completed the standardization of the cards, edited the typed manuscript, and read the proofs of the index.

2. *Other investigations*—Dr. Pogo has continued his study of the astronomical knowledge of the Egyptians of the ninth to eleventh dynasties. Much of his time was devoted to the editing of *Isis*.

Miss Welborn pursued her investigations relative to science in the Fourteenth Century, especially to botany and medicine.

3. *Publication of Isis*—During the past year, with Dr. Pogo acting as editor, five numbers of *Isis* have been published (47 to 51), forming the end of volume 15 (pages 504-630), volume 16 (586 pages), and volume 17 (636 pages), a total of 1349 pages, 31 plates, and 13 figures. They contain 37 papers, 87 shorter communications and reviews, 1825 bibliographical notes, and Mr. L. Guinet's general index to volumes 13 to 15.

4. *Lectures*—Dr. Sarton delivered four lectures to the American University of Beirut, one to the Muslim College of the same city, and two to the Hebrew University of Jerusalem. These lectures were largely devoted to the explanation of Arabic science, and of the medieval sources of our knowledge and our culture. These sources were partly Jewish, partly Christian, partly Muslim. The Jews alone would have failed, the Christians alone would have failed, the Muslims alone would have failed. Together they succeeded, and each of us owes gratitude to all of them.

#### RESEARCH IN PALEOGRAPHY, BY E. A. LOWE<sup>1</sup>

As in the preceding year, the half-year not spent in Oxford was devoted to field work, and some field work was also done in the week-ends of the two terms spent in Oxford, visits having been made to Cambridge, Durham, Worcester, Glasgow, and the British Museum. On the Continent, work was done in the libraries of Paris, Florence, Milan, and Rome, by far the longest period having been spent at the Vatican Library. Once more, very warm thanks are due to the officials of the Vatican Library for the extraor-

<sup>1</sup> For previous reports see Year Books Nos. 9 to 30.

dinary permission to examine in the stacks the entire Palatine collection of nearly 2000 manuscripts. Special thanks are also due to the Prefect of the Ambrosian Library for his great kindness in permitting work even on Sunday.

After returning from Italy in April, all effort was concentrated upon putting in shape for press the material of the first fascicule of *Codices Latini Antiquiores*. This fascicule deals with the manuscripts of the Vatican City and comprises 130 items. Collotype proofs of all the 130 specimens have already been seen, the entire letter-press is now set up, and barring unforeseen obstacles the first fascicule should be published by the Clarendon Press before the end of the year.

Apart from work on *Codices Latini Antiquiores*, interesting material has been collected throwing light upon certain aspects of the making of books in ancient times. The article on South Italian Manuscript of Virgil has also been seen through the press, but publication has been delayed due to present conditions; and one review was written.

At the invitation of the Director of the American Academy in Rome a lecture was given there at the end of February.

This report can not close without mention of the close cooperation of the officials of the Clarendon Press with the editor of *Codices Latini Antiquiores*, without which progress would have been considerably slower and the task rendered very much more difficult.

#### HISTORY OF GREEK THOUGHT, BY W. A. HEIDEL<sup>1</sup>

Dr. Heidel spent the months July to October in Munich working in the Staatsbibliothek, where he found abundant materials, especially older German publications relating to the history of Greek science and philosophy. The librarian procured for his use certain very rare books, which had not been obtainable elsewhere. After a short visit to Berlin he went to Montpellier, where access was gained to some valuable manuscripts and records belonging to the École de Médecine. The data gathered there supplement those from Salerno and Naples regarding the history of medicine. From Montpellier Dr. Heidel went to Rome, working steadily in the Vatican Library, until the roof collapsed, and thereafter, until April, in the German Archeological Institute, where there was found a surprisingly good collection of books. In Florence, later, Dr. Heidel discovered a medical manuscript of importance in the Laurentiana, which had been too lightly passed over before, and extracted some valuable data therefrom. After some weeks in Paris, searching for materials in the Bibliothèque Nationale, where he found little to his purpose, except manuscripts, he returned, the end of May, to London, where he has since worked in the British Museum. He expects to be in England until October, when he returns to the United States.

Dr. Heidel reports the past year to have been very profitable for his studies, giving opportunity of rounding out his collection of materials and of maturing his reflection on their significance. By the time he returns home he hopes to have filled the principal lacunæ and to be ready to do the writing which is only possible under settled conditions.

<sup>1</sup> For previous reports see Year Books 29, 30.





# DEPARTMENT OF MERIDIAN ASTROMETRY<sup>1</sup>

BENJAMIN BOSS, DIRECTOR

The work of this Department during the past year has been principally one of amassing figures in the process of formation of the General Catalogue. While the statistical details covering the progress of such an undertaking are not very exciting and do not lend themselves to the compilation of an interesting report, it is at least gratifying to those engaged upon this huge undertaking to note the great strides forward which have been accomplished during the past year, as measured by these statistics.

In addition to the computations involved in the formation of the star positions and motions, corrections to the system of the Preliminary General Catalogue have been nearly completed.

In conformity with international request, both formal and through private communication, the General Catalogue will employ the epoch 1950, as representing a mean date more nearly that of modern observations than 1900. In this connection it is well to note that the second revision of Auwers' system will likewise employ the epoch 1950. Since no tables of precession for 1950 are available, this means considerable more computation necessary for the completion of the General Catalogue.

## THE GENERAL CATALOGUE

### REDUCTIONS

In the process of determining the positions and motions of the stars which will constitute the General Catalogue, a provisional star place is adopted for the year 1875 and an ephemeris is then formed by expanding the 1875 position to the mean dates of observation as given in the catalogues which list the star. The ephemeris is then compared with the observed place to form residuals. To the residuals, systematic corrections to the various catalogues are applied. The star sheets and the application of the systematic corrections are now finished for all stars except the southern circumpolars from  $80^\circ$  to the pole.

The resultant corrected residuals are then drawn off to form conditional equations, which are solved for a correction to the adopted position of the star and for proper motion. The conditional equations are complete for all stars except 500 P.G.C. stars and the northern and southern circumpolar stars from  $80^\circ$  to the pole, and they have been checked.

All the normal equations for the 11,800 northern miscellaneous stars have been formed, and 6700 of these have been solved and checked in both coordinates. Normal equations have been formed for 3000 P.G.C. stars, 1300 of which have been solved and checked.

Revision of data relating to binary stars is complete and nearly checked.

The extension of the ephemerides to 1950 is complete for the P.G.C. and northern miscellaneous stars and to 16 hours of right ascension for

<sup>1</sup> Address: Dudley Observatory, Albany, New York.

the southern miscellaneous stars. About two-thirds of these extensions have been checked.

Precessions and secular variations have been computed for 1000 northern stars.

#### SYSTEMATIC CORRECTIONS

Raymond has completed the discussion of the systematic corrections in declination depending upon declination to the P.G.C., utilizing 77 catalogues regarded as of fundamental value, 57 from northern observatories and 20 from southern. In addition 12 northern and 4 southern authorities were used for stars in the polar regions only. After correcting these catalogues for indicated errors they were compared in pairs, one from a northern observatory with one from a southern. As a rule each catalogue was compared with all those available whose epochs were within ten years of the epoch of the given catalogue, correcting them first by preliminary values of the proper motions. Normal equations were formed for the correction to declination depending upon declination and for the correction

#### *Declinations*

$\delta$	$\Delta\delta$ 1900	$\Delta\mu_\delta$	Epoch	$\delta$	$\Delta\delta$ 1900	$\Delta\mu_\delta$	Epoch
+88°	+0".01	-0".02	1898	0°	+0".17	+0".14	1894
80	.01	+ .03	93	-10	.17	.18	94
70	.03	.05	93	20	.18	.23	99
60	.06	.01	93	30	.18	.23	97
50	.21	.20	93	40	.27	.38	96
40	.26	.33	93	50	.31	+ .38	96
30	.26	.36	94	60	.16	- .07	96
20	.28	.36	94	70	+ .02	.30	96
+10	.22	.17	94	80	.00	.12	98
0	+ .17	+ .14	1894	-88	.00	- .02	1898

#### *Right Ascensions*

47 Catalogues				95 Catalogues		
$\delta$	$\Delta\alpha_\delta$ 1900	$\Delta\mu_\delta$	Epoch	$\Delta\alpha_\delta$ 1900	$\Delta\mu_\delta$	Epoch
+80°	-0.031	-0.091	1892	-0.031	-0.095	1889
70	.024	.059	92	.025	.059	88
60	.014	.046	92	.015	.039	87
50	.009	.037	92	.009	.023	88
40	.003	.022	92	.004	.011	88
30	.004	.017	95	.005	.011	90
20	.000	- .002	95	- .001	- .001	90
+10	.000	+ .004	95	+ .001	+ .002	90
0	.000	+ .004	1895	+ .001	+ .002	1890
-10	+ .001	- .001	95	+ .001	+ .002	89
20	.001	+ .004	92	.001	.004	90
30	+ .001	.000	1903	+ .001	.005	95
40	- .005	- .018	03	- .006	.001	98
50	+ .005	+ .006	04	+ .001	.024	98
60	.018	.064	04	.017	.072	98
70	.049	.124	04	.044	.143	98
80	+ .128	+ .305	1904	+ .119	+ .330	1898

to proper motion depending upon declination over  $5^\circ$  zones from pole to pole. An abridged table of results appears on page 130.

A similar solution for right ascension depending upon declination and for proper motion in right ascension depending upon declination is now complete from  $+80^\circ$  to  $-80^\circ$ . Three solutions were made. The first depends upon 47 of the strongest catalogues; for the second, 44 additional catalogues were used; and Bradley 1755, Hornsby 1785, Auwers-Pond 1817 and Königsberg 1817 were included in the third. An abridged table of results appears on page 130. The discussion of circumpolar stars may slightly alter the values at  $+80^\circ$  and  $-80^\circ$ . There is little doubt that the first solution utilizing 47 strong catalogues is to be preferred, and it is adopted.

The question of the adoption of an equinox correction led to an examination of the subject and resulted in the adoption of a correction of  $-0_s.04$ . There appears to be some uncertainty in the determination of this constant, which appears to undergo secular variations of unknown source. Due to these uncertainties, it appeared inadvisable to change Newcomb's value of the precession.

## MISCELLANEOUS INVESTIGATIONS

### STELLAR MOTIONS

Wilson has completed the study of the motions of the stars in the Taurus cluster and its associated group mentioned in the report of last year. From the proper motions of 136 stars within  $20^\circ$  of the center in Taurus and the radial motions of 60 of them, the direction of the cluster motion is found to be  $\alpha=92^\circ.2$ ,  $\delta=+28^\circ.7$ , and the speed, 31.2 km/sec. The mean parallax of the cluster is 0'.0250, giving a distance of 40 parsecs. The maximum dimension is about 18 parsecs. Whereas but 58 stars scattered over the sky should be moving toward an area with a radius of  $22^\circ$  surrounding the cluster apex with speeds differing not more than 10 km/sec. from the cluster speed if the motions were distributed at random, 221 such stars were found. These are called "group" stars. The distribution of spectra in the cluster and group are similar. Both appear as Type I open clusters; *i.e.* the brightest stars are of Class A, red and yellow giants are present, and the greater proportion of the stars in each belong to the main sequence. Studies of the peculiar motions show a continuity of motion increasing from the center of the cluster outward to the group. The space distribution of the group stars is such that one may picture them as composing a giant globular cluster nearly 250 parsecs in diameter, the restricted cluster in Taurus possibly marking the center, but the data at present available are not sufficient to establish between the cluster and group connections more intimate than community of motion and similarity of spectra.

A similar study is being made of the stars which make up the so-called Ursa Major group, which is moving in a direction almost opposite to that of the Taurus group at about the same speed. These two groups appear to play an important part in determining general preferential motion within our local stellar system. The eleven stars located in the constellation Ursa Major are all moving within  $9^\circ$  of the mean apex at  $\alpha=287^\circ.5$ ,  $\delta=+1^\circ.0$ .

with speeds differing not more than  $2^\circ$  from the mean, 29.2 km/sec. Their observed parallaxes indicate a mean distance of 25 parsecs ( $\pi=0''.0409$ ) and a maximum diameter of not over 10 parsecs. 252 stars scattered over the sky are found to be moving within  $25^\circ$  of the cluster apex, where 75 would be expected if the motions of all the stars of similar speeds were random. The apices of 206 of these stars fall within  $22^\circ$  of the mean apex at  $\alpha=287.5$ ,  $\delta=\pm 0^\circ.0$ , and their mean speed is 28.6 km/sec. Like the Taurus group, the Ursa Major group is composed largely of main sequence stars, accompanied by red and yellow giants, mainly of classes G5 and K0. The brightest stars are practically all of class A. Whereas in the Taurus group the F-stars are most numerous, in the Ursa Major group the A-Stars are definitely the most numerous. Whether or not this difference is real can only be determined when we shall have derived the motions of a considerable number of the fainter stars. Since the brighter stars of both groups are of A type and the fainter ones mainly of later type, the data now extant may be nearly complete for the A-stars and not at all representative of the actual numbers of dwarf members of the later types.

The part played in the preferential stellar motion by the stars moving toward the Taurus and Ursa Major apices with common speeds seems pretty definite. These stars alone are numerous enough to produce a semblance of preferential motion, since the more numerous stars with lessers speeds are moving essentially at random. It has been pointed out in previous reports that these apices are not  $180^\circ$  apart. This is due in large measure to uncertainty in what we choose to call the solar motion. In most investigations the solar motion derived from the weighted mean motions of stars of all speeds has been used. This is not truly representative of the stars with speeds 20 to 40 km/sec., and hence not of the Taurus and Ursa Major groups. It may be assumed that these groups belong wholly to the local system. If the solar motion within the local system be removed from the motion, the apices of the two groups are approximately  $170^\circ$  apart.

#### STELLAR LUMINOSITIES

A study by Wilson of stellar luminosities based upon all available measures and estimates of parallaxes shows that the observed distributions within spectral sub-divisions follow with a pretty fair degree of accuracy normal error curves based upon a minimum of four frequency distributions represented by the main spectral sequence, ordinary giants, supergiants and faint giants. These results confirm those of Stromberg in which these four distributions were evidenced from studies of peculiar, parallactic and radial motions.

#### COOPERATION

New proper motions of 389 stars contained in the Preliminary General and General Catalogues were determined in advance at the request of Professor S. A. Mitchell of the McCormick Observatory. These were sent to him in April to serve as standards for the motions of some 18,000 stars measured on the McCormick plates.



The positions of 78 stars were furnished to Professor E. W. Brown of Yale University for use in his reductions of observations of occultations.

Revised positions of three bright stars for the year 1786 were furnished to Professor J. H. Pitman of Swarthmore College and were used by him in a discussion of the Rittenhouse latitude observations of that year. The widely discordant latitudes derived\* at that time from the separate stars were brought into good agreement with the new positions for that date based upon modern observations.

#### STAFF

The personnel of the staff has not changed during the past year. Five part-time computers have been employed at various times during the year.



# MOUNT WILSON OBSERVATORY<sup>1</sup>

GEORGE E. HALE, HONORARY DIRECTOR  
WALTER S. ADAMS, DIRECTOR  
FREDERICK H. SEARES, ASSISTANT DIRECTOR

In reporting the work of a year which has been characterized by new developments in a variety of fields it is especially appropriate to refer to the methods and processes which have made possible many of these investigations. Every field of astronomical research is in the end limited by the light-gathering power of the telescope and the degree of efficiency with which the light is utilized in the auxiliary instruments. Telescopes may be made larger; cameras, spectroscopes, photometers and radiometers may be made more efficient; and the sensitiveness of the photographic plate may be increased. Advances in any one of these directions open up new possibilities, the limits of which can not be predicted.

The Observatory has already benefited in many ways from its close association with the preliminary investigations relating to the 200-inch telescope of the California Institute of Technology. The development of a very short-focus lens by Dr. Rayton has made it possible to photograph the spectra of extra-galactic nebulae to distances much greater than could be reached previously. A special type of correcting lens designed by Dr. Ross to enlarge the field of the reflecting telescope has given results of great value and is being applied widely both to direct photographic and to spectroscopic investigations. Recent studies of the radiometer by Dr. Smith have added new importance to the use of this instrument in the laboratory and for astronomical photometry. To all of these instrumental advances the Observatory has contributed its experience and its facilities and has gained to a corresponding degree in their successful utilization.

The most recent illustration of a cooperative investigation of great value is that by Dr. Stebbins, Research Associate of the Carnegie Institution, and his assistants at Madison, on the amplification of the small currents involved in photoelectric photometry of stars by means of the thermionic tube. Through evacuation of the chamber containing the tube and photoelectric cell, Mr. Whitford, assistant at the Washburn Observatory, has succeeded in eliminating most of the irregularities of the installation and in increasing the effective sensitivity to at least four times that of the cell and electrometer used previously. Grants from the National Research Council and the California Institute of Technology will provide for a continuation of these experiments during the coming year and for the construction of a photometer of this design for the 100-inch telescope. It is expected that the limit for useful measures of the light of nebulae will be extended from the thirteenth to nearly the fifteenth magnitude.

The contribution made by Dr. C. E. K. Mees, Director of the Research Laboratory of the Eastman Kodak Company, to astrophysics and to many branches of science through the development of photographic plates of high sensitiveness to the red and infra-red portions of the spectrum, is one which

<sup>1</sup> Address: Mount Wilson Observatory Office, Pasadena, California.

can not fail to be recognized most gratefully by every investigator in these fields. It has made possible researches previously quite impracticable and has extended spectroscopy into a new and most important region. The discovery and identification at Mount Wilson of new bands in planetary spectra, the photography of the fundamentally important Paschen series of hydrogen lines and other details in stellar spectra, and the extension of the solar spectrum far toward the red are but a few of the first results to be obtained from this extremely valuable work of Dr. Mees.

The long and difficult series of measurements of the velocity of light with the evacuated pipe-line at the Irvine Ranch, which was initiated by Dr. Michelson and has been continued since his death by Pease and Pearson, will be brought to a close this summer. The reduction and study of the measures will require considerable time, but there is every reason to believe the final results will form a notable contribution to the determination of this fundamental physical constant.

#### STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has carried on solar observations and a study of the sun's general magnetic field, and has given much time to plans relating to the 200-inch telescope. Dr. Walter S. Adams, Director, has remained in charge of the administration and has continued investigations in stellar spectroscopy. Dr. Frederick H. Seares, Assistant Director, has shared in the administrative work, and, in addition to serving as editor of the Observatory publications, has conducted researches in stellar photometry and stellar statistics.

Dr. John A. Anderson has divided his time between activities connected with the 200-inch telescope project, of which he is Executive Officer, and laboratory investigations on the high-current vacuum tube. Dr. Arthur S. King, Superintendent of the Physical Laboratory, has been engaged in the analysis and classification of the spectra of numerous elements, especially the rare earths, as observed in the electric furnace and other sources. Dr. Edwin P. Hubble has devoted all his time to nebular investigations, including studies of distribution, brightness, distance and other characteristics. Dr. Paul W. Merrill has continued physical studies of bright-line B-type stars and other interesting stellar spectra. Mr. Harold D. Babcock has given his time to work with the ruling machine and to further researches on the infra-red spectrum of the sun. Professor Alfred H. Joy has observed the spectra of many variable stars of different classes and has derived their radial velocities. Dr. Seth B. Nicholson has been engaged in studies of sun-spot activity and many related problems. Dr. Francis G. Pease has been occupied chiefly with measurements of the velocity of light. Dr. Adriaan van Maanen has continued observations of stellar parallax and proper motion. Dr. Roscoe F. Sanford has measured the radial velocities of spectroscopic binaries and other stars of variable velocity. Dr. Edison Pettit has studied the forms and motions of solar prominences and has continued measurements of the ultra-violet radiation of the sun. Dr. Walter Baade, who joined the staff of the Observatory in October 1931, has given his time to the direct photography and photometry of nebulae and star clusters. Dr. Gustaf Strömberg has made statistical investigations of the



frequencies of different absolute magnitudes among stars of various spectral types. Dr. Theodore Dunham jr. has been active in the development of photometric standardizing methods and has continued his studies of high-dispersion stellar and planetary spectra. Mr. Milton L. Humason has been successful in extending his observations of the spectra of the extra-galactic nebulae to fainter magnitudes. Dr. Sinclair Smith has given part of his time to work at the Seismological Laboratory, but has also carried on photometric observations and experiments with radiometers and photoelectric cells. Mr. Ferdinand Ellerman has taken part in the solar observations and has cared for much of the photographic work of the Observatory. Dr. Robert S. Richardson has given special attention to the study of the hydrocarbon bands in the solar spectrum. Mr. Joseph Hickox has been the regular solar observer on Mount Wilson and has had charge of the astronomical exhibits.

Most of the work with the large microphotometer on the contours and intensities of solar and stellar spectrum lines has been carried on by Miss Louise Ware. Miss Elizabeth E. Sternberg has measured the positions and areas of sun-spots and has assisted Dr. Nicholson in the preparation of data on the solar activity. Mr. Edward F. Adams has given most of his time to the measurement of spectrograms for the solar rotation. Miss Myrtle L. Richmond has carried on reductions of the photographs showing the ultra-violet radiation of the sun and has aided in computations of cometary positions. Mr. Howard C. Willis has taken part both in the observational work on trigonometric parallaxes and proper motions and in the measurement and reduction of the photographs. Miss Mary C. Joyner has assisted Dr. Seares in photometric and statistical investigations. Miss Cora G. Burwell has been associated with Dr. Merrill in studies of the spectra of bright-line stars. Miss Elizabeth MacCormack has carried on measurements of radial velocity and computations relating to stellar motions. Mr. Olin C. Wilson jr., who joined the staff on July 1, 1931, has shared in the radial velocity work and has also undertaken studies of the contours of spectral lines in selected stars. Miss Ada M. Brayton has divided her time between computations of the spectroscopic absolute magnitudes of stars and the measurement and reduction of laboratory spectra. Mr. William H. Christie has carried on spectroscopic observations, measurements of radial velocity and photometric studies with the moving-plate camera. Mr. Wendell P. Hoge has aided Mr. Babcock in the investigation of the infra-red solar spectrum. Miss Elizabeth Connor has continued in charge of the library and has assisted in editorial work.

Dr. Henry Norris Russell, Director of the University Observatory of Princeton University and Research Associate of the Carnegie Institution, spent three months of the autumn of 1931 in Pasadena, engaging in researches on the constitution of stellar atmospheres. Dr. Joel Stebbins, Director of the Washburn Observatory of the University of Wisconsin and Research Associate of the Institution, carried on observations of stars and extra-galactic nebulae with his photoelectric photometer between September 1931 and February 1932. Dr. Stebbins returned for further work early in June. Dr. Charles E. St. John, Research Associate, has been engaged in

measurements of the solar rotation and the contours and intensities of solar spectrum lines.

Dr. Willem de Sitter, Director of the Observatory of Leiden, lectured on several occasions before the members of the staff during his visit early in 1932. Dr. Charles G. Abbot, Secretary of the Smithsonian Institution, returned to Mount Wilson in June to undertake investigations of energy in the infra-red solar spectrum. Dr. Fred E. Wright, of the Geophysical Laboratory of the Carnegie Institution, continued during the autumn of 1931 his studies of the surface features of the moon. Dr. Frank E. Ross, of the Yerkes Observatory, has carried on direct photography with his wide-angle lens and with the 60-inch reflector during the past two summers. Dr. W. F. Meggers and Mr. C. G. Peters, of the Bureau of Standards, investigated the spectra of certain of the rare earths with high dispersion during July and August 1931. Dr. John C. Duncan, Director of the Whittin Observatory, made photographic observations of nebulae and star clusters during his visit between April and August 1931. Professor F. E. Carr returned to Oberlin College in May 1932, after a stay of six months during which he carried on photometric investigations. Mr. E. G. Williams and Mr. L. E. Lefèvre, Commonwealth Research Fellows, have been in Pasadena since October 1931, and are engaged in researches in stellar spectroscopy. Dr. Serge A. Korff, National Research Fellow in Physics, has spent the year in Pasadena carrying on studies of line-contours in solar and laboratory spectra.

Among scientists who have visited the Observatory for briefer periods of time, but whose interest and counsel have been of great value to its work, have been Dr. C. E. K. Mees, Director of the Research Laboratory of the Eastman Kodak Company, Dr. Harry H. Plaskett of Oxford University, Dr. Arthur L. Day, Director of the Geophysical Laboratory of the Carnegie Institution, and Dr. H. Spencer Jones, Director of the Royal Observatory at the Cape of Good Hope.

#### SUMMARY OF THE YEAR'S WORK

Solar activity as measured by the average daily sun-spot numbers declined from 3.8 in 1930 to 2.3 in 1931, and at present indicates that the next minimum will probably occur in 1933 or 1934. Polarities have been observed for 150 groups of spots, all of which were regular, with no indication among the few spots in high latitudes of the reversal of polarity which marks the forerunners of the new cycle.

Direct photographs of the sun were made on 299 days between July 1, 1931, and June 30, 1932, by Ellerman, Hickox, Nicholson and Richardson, and 1021 spectroheliograms were obtained in hydrogen and calcium light. Estimates of the areas of flocculi and measures of the areas and positions of sun-spots, both of which serve as indices of solar activity, have been continued regularly.

Studies by Pettit of eruptive prominences, and especially of the great prominence of August 6, 1931, which reached a height of 620,000 km. and showed a maximum velocity of 126 km./sec., agree in showing a uniform motion of ascent with occasional sudden increases in velocity. The similarity of prominence forms in hydrogen and calcium light indicates a

thorough mixture of the two kinds of atoms. The density of the expanding head of the prominence of August 6 was found to vary as the sixth power of the distance from the solar center, the same law that was found previously for the coronal atmosphere. From his observations, Pettit has been led to a classification of prominences into active, eruptive, spot, tornado and quiescent, and to form estimates of their average dimensions. He also concludes that ordinary and so-called "metallic" prominences differ only in brightness, and that with sufficient exposure the prominence spectrum would duplicate that of the chromosphere except for some of the lines of the heavier elements.

Hale is taking advantage of the low state of sun-spot activity for further investigation of the sun's general magnetic field. He has developed new methods of measurement with the microphotometer and will use the recently improved photographic plates in the red region of the spectrum where the Zeeman displacements are largest.

From a study of the distribution of intensity in the hydrocarbon band at  $\lambda 4300$ , Richardson finds a difference of  $1650^\circ$  between the highest and lowest levels in the reversing layer at which CH molecules can exist in any quantity. In addition to analyzing two of the levels of the CH molecule and determining its moment of inertia, he has derived from the relative intensities of the lines in the  $\lambda 4300$  band in sun-spots and in the reversing layer a ratio of 0.5 for the pressure in spots to that in the reversing layer. From photometric reductions of photographs taken through color screens, Nicholson and Richardson have found, in the case of large sun-spots, temperatures as low as  $3800^\circ \text{C}$ .

From a study with the microphotometer of the ratio of the energy absorbed in spectrum lines of different intensity to the energy in the continuous background, St. John finds that lines in the green at one-half the height of the absorption curve are 1.29 times wider than lines of the same Rowland intensity in the blue and that the total absorption is 1.27 times greater. A logarithmic plot of the widths against the theoretical number of atoms active in producing a line indicates that this number is smaller in the green than in the blue and raises the question of the applicability of theoretical laboratory intensities to solar absorption lines. From measures of the contours of the D lines of sodium and the b lines of magnesium in the sun, Dr. Korff concludes that the wings agree with the contours predicted from theory, provided they are fitted at a point where about 80 per cent of the light of the continuous background is transmitted.

Measures by St. John over a period of several years indicate a gradual increase in the linear velocity of the sun's rotation at the equator, the present value being nearly 2.00 km./sec. The apparent change is not associated with the 11.2-year sun-spot cycle. From spectroscopic observations, Nicholson concludes that measures of this kind may be affected to the extent of 1.5 per cent by scattered light.

Babcock has completed his determinations of wave-length for 3200 lines in the region  $\lambda 7330$  to  $\lambda 9931$  and has added about 1700 lines to the list in the Supplement to the Revision of Rowland's Table. About 250 standards have been measured in the region  $\lambda 7330$  to  $\lambda 11204$  with relative values probably accurate to one part in two million. Babcock has also measured



about 400 lines in the oxygen bands chiefly for use in the determination of the masses of the oxygen isotopes.

The monthly averages of the ultra-violet radiation of the sun as measured by Pettit have been low during recent months; the means for the year 1931 and for the first six months of 1932 are the lowest since the beginning of the observations in 1924. From observations in Pasadena, Pettit finds for the ultra-violet limit of direct sunlight: in midsummer  $\lambda 0.290\mu$ , in mid-winter  $\lambda 0.296\mu$ ; for skylight the corresponding values are  $\lambda 0.295\mu$  and  $\lambda 0.298\mu$ . A determination of the ultra-violet solar energy curve made at Tucson, Arizona, in May 1931 gave a thickness of 0.18 cm. for the ozone layer at that time.

Investigations within the solar system have included further observations of lunar formations and additional work on the preparation of a large-scale map of the moon by Dr. Wright; the identification of Comet Neujmin (1913 III) when of about the sixteenth magnitude and the computation of a corrected ephemeris by Nicholson; and studies of planetary spectra by Adams and Dunham. With the aid of high-dispersion spectrograms, three new bands have been discovered in the spectrum of Venus and identified with reasonable certainty as due to carbon dioxide. Dunham has also found new bands in the spectrum of Jupiter and has resolved them sufficiently to make studies of their identification feasible.

The addition of about 6000 nebulae found by Hubble in his photographic survey of nebular distribution strengthens previous conclusions without materially altering the numerical results. A systematic series of photographs, under uniform conditions, of all extra-galactic nebulae brighter than magnitude 14 is being undertaken for the zone between declinations  $0^\circ$  and  $+15^\circ$ . Hubble and Baade have discovered several new clusters of nebulae, in one of which, in the constellation of Leo, about 300 nebulae appear within a circle  $36'$  in diameter. The faintest cluster known at present was found by Baade in the constellation of Coma; its brightest members have a photographic magnitude of about 19.0.

Measures of motions in spiral nebulae are being continued by van Maanen on photographs taken ten or more years apart, and photometric determinations of total magnitudes and colors are being made by Dr. Stebbins with a photoelectric cell. Results already obtained for about 40 nebulae show that the diameters are substantially larger than those estimated from direct photographs. The colors show a moderate range around a mean color class G8, while the mean spectral type is about G3. The moving-plate camera has been found to be well adapted for nebular photometry.

Hubble has provisionally identified 140 nebulous objects in the Andromeda nebula as globular clusters. Their absolute photographic magnitudes range from  $-4$  to  $-7$  and their diameters from 4 to 16 parsecs. A spectrogram of one of these objects by Humason shows a spectral type of F0 and a radial velocity corresponding to that of the nebula. Similar objects are found in four other nebulae.

Four spectrograms by Humason of the two brightest nebulae in the Gemini cluster give red-shifts corresponding to a velocity of  $+24,000$  km./sec. Spectrograms of nebulae in two fainter clusters suggest still larger shifts, but the results can not yet be interpreted with confidence.



Of the 22 stars for which trigonometric parallaxes have been measured during the year by van Maanen, assisted by Willis, 11 are found to have photographic absolute magnitudes fainter than +10. One of these, Ross 248, has an absolute magnitude of +16.3. Willis has measured the proper motions of 2178 stars in 113 fields and finds preliminary corrections to the motions in Boss's Catalogue of +0.001 in right ascension and +0.011 in declination.

Strömberg has designed an interferometer for the observation of double stars which with fair seeing should extend the range of measurement to separations of 5".

In the field of stellar photometry Seares and Miss Joyner have completed the determination of photovisual magnitudes in 42 Selected Areas; Christie has applied the moving-plate camera successfully to the magnitudes of variable stars; and Stebbins and Smith have used photoelectric photometers in the study of magnitudes and colors of stars between magnitudes 10 and 15. For B-type stars fainter than 8.0 near the central line of the Milky Way, Stebbins finds a color excess, due presumably to selective absorption, similar to that already found by him for the brighter B stars. Seares has determined the systematic scale and color corrections for nine catalogues of polar stars, and is using the results in the preparation of mean magnitudes for 200 additional polar standards.

Baade is making a detailed photometric study of the globular star cluster N.G.C. 2419, an object nearly opposite in position to the center of the galaxy, and, judged by the brightness of its stars, the most remote cluster of its class. The 27 variables thus far discovered give a provisional distance of 72,000 parsecs. Other investigations on globular clusters include the discovery by Hubble of 15 new variables in N.G.C. 7006; measures of radial velocity by Humason of five clusters with spectra hitherto unobserved; and photometric observations by Stebbins which indicate that several of the clusters situated in obscured areas of the sky show color indices considerably larger than those of normal M-type stars.

The method developed by Seares for determining the space density of stars has led to the conclusion that the luminosity function for all spectral types together is not independent of distance, but that the frequencies of high-luminosity stars near the sun are greater than the average. Data on proper motions and mean parallaxes of stars of magnitudes 13 to 17 collected by van Maanen and Willis indicate that the frequencies of low-luminosity stars continue to increase to at least absolute magnitude 14, and fix the space density of stars near the sun at a minimum of 9 or 10 stars per 100 cubic parsecs.

From a study of the obscuring clouds shown on Dr. Ross's photographs of the Milky Way, Seares concludes that allowance for absorption will remove much of the 5 to 1 disparity between the dimensions of our own system and those of the Andromeda nebula. There would still appear to remain, however, a large difference in mass.

Of the 1269 stellar spectrograms obtained during the year, 104 were made with the coudé spectrograph. This instrument has been adapted for use with a plane grating, the 15-foot lens and the 53° prism have been refocused,

and a step-slit attachment by Dunham gives calibrating spectra photographed simultaneously with the stellar exposure.

Radial velocity determinations have been completed for about 120 stars. Joy has now measured approximate velocities for 102 Cepheids and with the aid of these very distant objects is studying the rotation of the galaxy. Sanford and Joy have under observation a large number of Cepheids, Algols, and other variable stars, and Christie and Miss MacCormack are determining the orbits of several spectroscopic binaries. Other results include Sanford's measurements of the radial velocities of N-type stars, and similar measures by Humason of stars in the Selected Areas; studies of the detached sodium and H and K lines by Merrill and Sanford; and measures of planetary and stellar spectra taken with the coudé spectrograph.

In their survey of B-type stars with emission lines, now brought to a close, Merrill, Humason and Miss Burwell have found 233 objects with one or more bright hydrogen lines. All except 11 are of type B or closely related classes. Physical studies of all these spectra have been undertaken and a catalogue of all known stars has been prepared for publication. With the aid of the microphotometer Wilson is comparing the intensities of detached  $D_1$  and  $D_2$  with those of the absorption lines of hydrogen in selected stars of type B.

Merrill has found some remarkable stellar spectra showing lines associated with gaseous nebulae. These objects appear to be intermediate between planetary nebulae and ordinary Be stars. Merrill has also discovered three stars with spectra showing the bright line of helium at  $\lambda 4686$  associated with absorption bands of titanium oxide. Joy and Merrill have studied the variable spectra of RT Serpentis, XX Ophiuchi and SX Herculis, and Merrill, in the course of his studies in the less refrangible region of stellar spectra, has identified the green auroral line  $\lambda 5577$  [O I] with a bright band present in novae, and has photographed 14 members of the Paschen series of hydrogen in the spectrum of  $\alpha$  Cygni.

Further investigations in stellar spectroscopy include a research on 45 variable stars with periods intermediate between those of the Cepheid and the Mira class, together with a study of their distribution, by Joy; the discovery of additional stars with bright H and K lines by Adams and Joy; the probable identification of secondary heads to the main bands of the carbon isotope in type R stars by Sanford; and the completion of the spectral classification of 4066 stars in the Selected Areas and an analysis of their distribution by Humason.

With the aid of new reduction tables Adams has determined the spectroscopic absolute magnitudes of 4000 stars of types A to M. The frequency diagram shows lines of maximum frequency for the supergiants, normal giants, and main sequence stars (including the dwarfs), from which the deviations in brightness are small. From A to M0 the mean brightness increases for the giants and decreases for the dwarfs in a nearly linear manner. The lines for main sequence stars and normal giants cross at F0; between F5 and G0 nearly all the more luminous stars are supergiants. The parallaxes derived from the spectroscopic absolute magnitudes of 1006 stars differ systematically from the trigonometric values in Schlesinger's Catalogue by 0".0004.

From radial velocities and parallactic and peculiar motions, Strömberg has calculated for each spectral type the distribution of absolute magnitudes among stars brighter than apparent magnitude 6.0. Lines of maximum frequency appear for supergiants, bright, normal and faint giants, and for main sequence stars. Continuity in the lines from type to type points toward the reality of the maxima, which, moreover, are in good general agreement with the distribution of spectroscopic absolute magnitudes.

Investigations of the distribution of energy in stellar spectra have involved a study of methods as well as observations at the telescope. Smith finds that the influence of bad seeing can probably be eliminated from radiometric measures by a photographic averaging of the deflections of the galvanometer over an interval of a minute or two. The radiometric microphotometer designed by Smith has been used by Wilson in an investigation of Nova Aquilæ. A photoelectric microphotometer provided with an amplifier, now greatly improved by Dunham, has been effectively used, chiefly by Dunham and Lefèvre, for the analysis of high-dispersion spectra of Cepheids and other stars. The Koch microphotometer, a thermopile-galvanometer combination, has been employed mostly on contours of solar lines. Finally, the 3-prism ultra-violet spectrograph has been used with a step-slit by Williams to observe the energy distribution of early-type stars.

Results by Russell on ionization and opacity in stellar atmospheres indicate that the atmospheric content is mostly hydrogen and that opacity is mainly a consequence of interaction between ions and free electrons. Below  $8000^{\circ}\text{C}$ . the total mass above the photosphere is nearly independent of temperature, but not of gravity. Ionization of the hydrogen greatly increases the opacity and thus reduces the effective depth of the atmosphere, a fact which accounts for the weakening of certain ionized lines in passing from type F5 to B9.

In the Physical Laboratory, King has continued his studies of the rare earths, classifying 2600 lines of neodymium according to temperature and measuring 1750 wave-lengths. Doubly ionized cerium has also been measured, 280 lines, by R. B. King. Europium and thulium have likewise had attention; and in cooperation with Dr. W. F. Meggers and Mr. C. G. Peters of the Bureau of Standards, the hyperfine structure of rhenium lines has been studied. A result is the nuclear moment of rhenium, found to be the same for both isotopes.

A study of the furnace spectrum of tungsten has been completed by King; examination of arc and spark spectra of tantalum has identified the enhanced lines and revealed previously unknown hyperfine structure; and observations of columbium by Meggers and King have given improved data on the difficult hyperfine structure of this element.

Furnace spectra of calcium, strontium, barium and neodymium studied by King show that when little of the element is present the enhanced lines are more persistent than the arc lines, probably because the opportunities for recombination of ionized atoms and free electrons are then few. The results harmonize with well-known features of stellar and nebular spectra.

The coreless solenoid magnet has been used by Mr. A. Wolf of the California Institute of Technology in a study of magnetostriction in crystals of bismuth. Up to 26,000 gauss at least, the change in length of the crystal



is roughly proportional to the square of the field-strength, and at this limit is one part in five million.

Anderson finds the energy distribution in the continuous spectrum of the high-current vacuum tube to be nearly that of a black body at 10,000° K. The intensity of radiation, however, is 14 times that of such a body, the radiation temperature ranging from 60,000° K. at  $\lambda$ 8000 to 28,000° K. at  $\lambda$ 4000.

Smith's studies of photoelectric cells have defined the limit of sensitivity, which is fixed by fluctuations in the number of photoelectrons set free by a given number of quanta. The photoelectric photometer used with the 60-inch reflector reaches the theoretical limit, and increased sensitivity with this type of instrument is not to be expected. Smith finds a special caesium oxide cell to be highly promising for stellar photometry because of its great red sensitivity, and, in collaboration with Dr. G. L. Locher of the Rice Institute, has studied the possibilities of a Geiger-Müller counter for astronomical photometry.

The contours of the D absorption lines of sodium produced by a long column of vapor have been found by Korff to agree with the classical theory and also with the quantum mechanical theory of Weisskopf and Wigner.

Under Babcock's direction nine gratings and numerous test rulings have been made with the old ruling machine. Except for the thrust bearing, the new machine is assembled and ready for optical tests of adjustment.

Measurements of the velocity of light, resumed by Pease and Pearson in April, will be concluded in August. Five or six thousand individual settings will then be available. The mean result agrees well with that reported last year, but a small periodic fluctuation is still to be explained. As a check, the optical path has again been measured by the U. S. Coast and Geodetic Survey.

#### OBSERVING CONDITIONS

Observing conditions during the year July 1, 1931, to June 30, 1932, were close to the average for the past 20 years. Solar observations were made on 299 days and stellar observations on 295 nights. The months of December, January and February were exceptionally stormy, but there was little precipitation after March 1. The total snowfall for the year was 100 inches, the third heaviest record since the establishment of the Observatory, but the total precipitation, 32.70 inches, was only slightly above the normal. The usual weather records have been maintained, with special observations at certain hours of the day and night for the use of the air-mail service.

The accompanying table shows the distribution of observing time with the 60-inch reflector throughout the year.

About 7800 visitors used the 60-inch telescope for visual observations during the Friday evenings of the year, when it is made available for the general public. Mr. Joseph Hickox has given the lectures on these occasions and has supervised the observations at the telescope. No record is kept of the visitors to the exhibit of astronomical photographs and the 100-inch telescope during daylight hours, but the number amounts to many thousands annually.

Interesting results on the darkness of the sky background at Mount Wilson as affected by the lights of Pasadena and Los Angeles have been



obtained by Dr. Stebbins with a portable photoelectric photometer. Measures referred to Polaris as a standard have been made at different times of night in both summer and winter. Similar measures with the same instrument have been made on Palomar Mountain on two occasions, at about the same altitude as on Mount Wilson, but remote from the influence of smoke

Month	Observations			Month	Observations		
	All night	Part of night	None		All night	Part of night	None
1931:				1932:			
July.....	26	4	1	January.....	13	7	11
August.....	24	4	3	February.....	13	2	14
September...	23	6	1	March.....	19	6	6
October.....	24	4	3	April.....	17	8	5
November...	12	11	7	May.....	20	9	2
December....	8	11	12	June.....	21	3	6
				Total.....	220	75	71

and city lights. The first result, in winter, showed the Mount Wilson sky to be from 0.25 to 0.5 mag. brighter than that at Palomar. The second comparison, in summer at a time when the Los Angeles region was covered with fog, gave practically the same brightness at the two stations. Except for observations made low down in the southwest, it is not likely, therefore, that long-exposure photographs at Mount Wilson are seriously affected by scattered light from the neighboring cities.

### SOLAR RESEARCH

Sun-spot activity continued to decrease during 1931 and the first half of 1932, but occasional large groups were visible. One of these, which crossed the central meridian on February 20, was readily visible to the naked eye and is to be listed among the 15 largest groups of the present cycle.

In addition to regular observations of the numbers, areas and polarities of sun-spots and daily records with the spectroheliograph, numerous spectroscopic investigations have been undertaken during the year. Owing to the approach of sun-spot minimum and the comparative freedom of the sun from the disturbing effect of the intense magnetic fields of spots, Hale has commenced a new investigation of the sun's general magnetic field. Nicholson and Richardson have undertaken preliminary experiments on the construction of a coronagraph of the type designed by Lyot for direct observations of the corona, and Dunham has been developing a method for recording directly the contours of solar absorption lines with a photoelectric cell and amplifying tubes.

### SOLAR PHOTOGRAPHY

Direct photographs of the sun were made with the 60-foot tower telescope on 299 days between July 1, 1931, and June 30, 1932, by Ellerman, Hickox, Nicholson and Richardson. For these photographs as well as for 35 spec-

tograms in  $H\alpha$  light, the 6.5-inch image was used; for the other spectroheliograms, the 2-inch image. The number of photographs obtained was:

$H\alpha$  image, whole sun.....331  
 $K_2$  image, whole sun.....279  
 Prominences in K light.....411

Regular interchanges of spectroheliograms with the Kodaikanal Observatory have been continued throughout the year.

#### SUN-SPOT ACTIVITY

During the calendar year 1931 solar observations were made on 309 days. No spots were visible on 32 days, of which 10 were in June and 7—June 19 to 25 inclusive—were consecutive. This was the longest interval without spots since January 1925. The greatest number of groups observed on a single day was 8, on February 26. The monthly means of the numbers of groups observed daily during the past two and one-half years are given in the accompanying table.

Month	Daily number			Month	Daily number	
	1930	1931	1932		1930	1931
January.....	6.7	1.8	1.8	July.....	2.7	2.3
February.....	6.2	4.0	1.2	August.....	2.7	1.9
March.....	3.4	3.0	1.2	September.....	3.6	2.1
April.....	4.0	3.8	1.0	October.....	3.0	1.4
May.....	3.3	2.7	2.1	November.....	3.2	1.8
June.....	3.3	1.4	2.2	December.....	2.9	1.8
				Yearly average..	3.8	2.3

The epoch of the last minimum has been placed at 1923.6, and of the last maximum at 1928.4, both dates being uncertain by some months. Since the sun-spot activity in 1931 was very similar to that in 1921, it seems probable that the next minimum will occur in 1933 or 1934.

The number of groups observed in the northern hemisphere of the sun decreased from 124 in 1930 to 94 in 1931, and that in the southern hemisphere from 97 in 1930 to 56 in 1931. The mean latitude of the spot-zones decreased from  $10^{\circ}4$  in 1930 to  $9^{\circ}2$  in 1931. No group was more than  $23^{\circ}$  distant from the equator, and only four groups were more than  $20^{\circ}$  distant. The magnetic polarities of these four were normal, thus indicating that none of them could be classed as a member of the next cycle.

Areas and positions of sun-spots on 39 days have been supplied to the Naval Observatory for publication in the Monthly Weather Review, and daily records have been communicated to Science Service at Washington. Estimates of character figures to serve as an index of solar activity were made on 278 days in 1931 for calcium flocculi, and on 274 days for hydrogen flocculi, and forwarded to the Solar Physics Committee of the International Astronomical Union at Zürich. Values for the earlier years 1923–1927 inclusive having already been provided from Mount Wilson, the series is

now being extended to include the years 1920, 1921 and 1922. This work is being carried on by Nicholson and Miss Sternberg.

#### SUN-SPOT POLARITIES

Observations of the polarity and intensity of the magnetic field in sun-spots were made on 242 days in 1931. The accompanying table shows the number of groups classified, "regular" groups in the northern hemisphere being such as show S (south-seeking), or negative, polarity for the preceding spot, and N polarity for the following spot, while the reverse is true in the southern hemisphere.

Hemisphere	Polarity		
	Regular	Irregular	Unclassified
North.....	71	0	23
South.....	38	0	18
Whole Sun...	109	0	41

#### SUN-SPOT TEMPERATURES

Nicholson and Richardson have photographed several spots through color screens and in the continuous spectrum at a number of wave-lengths, and have reduced the results by the methods of photographic photometry. Under the best observing conditions, temperatures as low as 3800° C. have been found in large spots. Studies of the effects of scattered light and poor seeing indicate that large corrections are necessary except under the finest conditions.

#### SOLAR GRANULATIONS

The spectrum of the sun as usually photographed is composite, owing to a mixture of the light from the bright granulations and the less brilliant solar background. For a satisfactory interpretation of the contours of solar lines we should know the differences between these two spectra, or at least the difference in temperature of the two sources. Dunham has obtained for this purpose, under good observing conditions, a number of photographs of spectra at the 60-foot focus of the Snow telescope, using a 20-inch camera with a plane grating. The spectra of individual granulations are shown clearly and should provide a determination of at least a minor limit to the difference in temperature.

#### ERUPTIVE PROMINENCES

Pettit spent the month of August 1931 at the Yerkes Observatory studying prominences with the Rumford spectroheliograph. The great eruptive prominence of August 6, which reached a height of 620,000 km. and showed a maximum velocity of 126 km./sec., afforded an exceptional test of the law of motion and of the appearance of the prominence in the lines of hydrogen and calcium. Two hundred and nine exposures made at the Yerkes

Observatory, 54 of which were at the eruptive stage, and 53 at Mount Wilson, together with 14 visual observations with spectroheliscopes, make this prominence probably the most completely observed on record.

Closely parallel measures by four individuals show a uniform motion of ascent with occasional sudden increases in velocity, as previously found in the cases best observed. A study of all available observations since 1920 corroborates this principle of motion and brings the total of known cases to 35.

Drawings of the prominence of August 6 made with the Yerkes spectrohelioscope in  $H\alpha$  are very similar to spectroheliograms in the  $H$  line of  $\text{Ca II}$ . The hydrogen and ionized calcium atoms seem, therefore, to be very thoroughly mixed in eruptive prominences, as had already been found for active prominences. In both types the only substantial difference between the hydrogen and  $\text{Ca II}$  images is the weakness or absence of the streamers from hydrogen images; and even this difference may be partly due to scattered light in the instruments.

Measurements of the expanding head of the prominence of August 6 show that its density varied inversely as the sixth power of the distance from the solar center. The volumetric density of the coronal light observed at the eclipse of January 24, 1925, was found to follow the same law. The density of an eruptive prominence seems therefore to keep step with that of the coronal atmosphere, and uniform upward motion might be expected, as in masses of gas rising in our own atmosphere. Since no relative displacement of the  $H\alpha$  and the  $H$  absorption lines was observed, it is doubtful if light pressure, which would drive the hydrogen and calcium atoms upward at different speeds, is the principal propelling force in eruptive prominences.

#### SPECTRA OF PROMINENCES

"Metallic" prominences, usually brilliant spikes often associated with sun-spots, show a larger number of spectral lines than the ordinary prominence observed without an eclipse. Measures by Pettit of a spectrogram of ordinary prominences made by Anderson and Babcock at the eclipse of June 8, 1918, show, however, all but two of the flash spectrum lines brighter than intensity 30, and 14 fainter lines. Since metallic prominences show all the flash lines brighter than intensity 15, excepting those of  $\text{Ba II}$ , it seems likely that ordinary and metallic prominences differ only in brightness and that with sufficiently long exposure the prominence spectrum would duplicate that of the chromosphere in all but the lines of a few of the heavier elements.

#### FORMS AND DIMENSIONS OF PROMINENCES

A study of prominence spectroheliograms by Pettit has led to the following classification, based on form and order of frequency: (1) active prominences, which appear to be torn apart by an area of attraction or by the disturbances of a neighboring sun-spot; (2) eruptive prominences, which ascend in more or less vertical directions; (3) spot prominences, often having the appearance of the closed loops of a fountain or of spikes with external wings, generally best described by the words "splash;" (4) tornado prominences, which appear like vertical spirals or tightly twisted ropes;



(5) quiescent prominences, which show only minor changes from minute to minute. Strictly speaking, all prominences are "active" and there is no such thing as a quiescent prominence. One of the best examples of the latter showed numerous internal motions of 5 to 10 km./sec., although velocities of 15 km./sec. were rare.

Prominences appearing as absorption markings on H $\alpha$  spectroheliograms show a remarkably narrow range of only 6000 to 12,000 km. in thickness, although some are 15,000 km. Few prominences are shorter than 60,000 km., and a length of 600,000 km. is unusual. The height is variable, but 75,000 to 100,000 km. is not uncommon. A representative prominence would be 50,000 km. high, 200,000 km. long, and 10,000 km. thick, a sheet of incandescent gas standing on edge slightly above the chromosphere and connected with it by columns like the roots of a tree. Its volume would be about 95 times that of the earth, with  $2 \times 10^{13}$  atoms of hydrogen per cubic centimeter and a negligible calcium content. The corresponding mass would be that of a cube of water 15 km. on the edge.

The prominence plates taken with the 13-foot spectroheliograph during the present sun-spot cycle show 17 cases of tornado prominences photographed with definition such as to reveal their spiral nature. These objects are small, 5600 to 22,000 km. in diameter and 25,000 to 97,000 km. high. In one instance the angular velocity became so high that the prominence exploded. No lateral motion on the solar surface was observed.

#### GENERAL MAGNETIC FIELD OF THE SUN

The plans developed by Hale for his new investigation of the general magnetic field of the sun include:

1. The use of a microphotometer or other special measuring device for eliminating personal equation.
2. The use of the spectrohelioscope for the selection of undisturbed regions on the central meridian of the sun.
3. The use of the improved photographic plates now supplied by the Eastman Company for work at the long-wave end of the spectrum.
4. The extension of the investigation into the infra-red in order to take advantage of possible larger Zeeman displacements and the probable increase of the field-strength at lower levels in the solar atmosphere.

The measurement with the microphotometer of the very small displacements on the successive strips of the photograph of the spectrum taken through the compound quarter-wave plate has involved many difficulties. These arise partly from the grain of the plate and partly from the narrowness (2 mm.) of the adjoining spectral strips and the variations in their density. A new device by Hale, designed to overcome these defects, is now under construction by Hitchcock in the shop of the Solar Laboratory. This will record displacements on twice the scale previously obtained and should reduce materially the effect of inequalities in the narrow mica strips of the quarter-wave plate. Several new methods of measurement have been devised in consultation with other men of science, including one suggested by Professor Einstein and another by Professor Newall. Seven different methods of measurement will thus be tested in the present investigation.

## TEMPERATURE GRADIENT IN THE REVERSING LAYER

Richardson has determined the temperature gradient in the reversing layer from the distribution of intensity in the P branch of the hydrocarbon band at  $\lambda 4300$ . The basis for this determination is the fact that if the temperature of an emitting gas is not homogeneous, the intensities of the band lines show a higher temperature for the higher rotational-energy levels than for the lower ones. The temperatures obtained from the intensities of the lines are:

Minimum .....	$4430^\circ \pm 160^\circ \text{ K.}$
Maximum .....	$6080 \pm 130$
Mean .....	$5080 \pm 120$

These results indicate a difference of  $1650^\circ$  between the highest and lowest levels in the reversing layer at which the CH molecules can exist in any quantity. When combined with data by St. John and Babcock, this difference gives for the region observed a temperature gradient of about  $13^\circ$  per km.

The relative pressure in sun-spots and in the reversing layer has been calculated from a formula developed from the theory of band-line intensities and the equation of dissociation equilibrium for molecules. The unknowns are the intensities of the lines and the temperatures in sun-spots and in the reversing layer. An inspection of the best spot spectrograms shows that selected lines in the P branch of the  $\lambda 4300$  CH band have practically the same intensity in the spot and in the reversing layer. This result gives for the ratio of the pressures: spot to reversing layer = 0.5.

In the course of this investigation Richardson has analyzed two of the levels in the CH molecule, determining the moment of inertia of the molecule in each state and representing, through the constants of the formula, 118 combination differences with an average deviation from the observed values of  $0.06 \text{ cm.}^{-1}$  or  $0.011 \text{ \AA.}$

## INTENSITIES AND CONTOURS OF SOLAR SPECTRUM LINES

St. John, assisted by Miss Ware, has measured the ratio of the energy absorbed in lines of different intensities in various parts of the spectrum to the energy of the continuous background in an interval of one angstrom. These ratios, which may be termed "equivalent widths," have been determined from microphotometer tracings. Some preliminary results based upon 100 lines of mean wave-length  $\lambda 4457$  and 80 lines of mean wave-length  $\lambda 5347$  are as follows:

1. For lines of the same Rowland intensity (a) the absorption at the center is practically the same in the two regions observed; (b) at one-half the height of the absorption curve the line width at  $\lambda 5347$  is 1.29 times that at  $\lambda 4457$ ; (c) the ratio of the respective total absorptions is 1.27, a result due mainly to the difference in width.

2. A logarithmic plot of the equivalent widths against the theoretical number of atoms active in producing a line indicates that this number is smaller in the green than in the blue. This result raises the question of the applicability of the theory of line-intensity derived from emission lines in the laboratory to solar absorption lines, a question already raised by the theoretical intensities of lines in multiplets.

In a comparative study of the contours of solar and laboratory lines Korff has photographed the D lines of sodium and the b group of magnesium with the 75-foot spectrograph. The contours measured with a microphotometer show wings agreeing with those given by the theory of radiation damping, provided the theoretical contours are fitted at a point where about 0.80 of the light of the continuous background is transmitted. A value of 0.50 has been used by most observers. Applying data obtained in laboratory experiments, Korff has investigated the effects of interaction widening, and finds that its contribution to the total width of the lines is small. Quantitative analysis of the constitution of the solar atmosphere based on scattering theory is found possible, provided the measurements of the widths of the lines are made in the wings.

#### SOLAR ROTATION

Recent changes in the measured values of the sun's linear velocity of rotation, as determined spectroscopically by St. John, assisted by E. F. Adams, give added interest to his long series of observations and increase the possibility of a change in the rotation period of the reversing layer. The rotation period of the photosphere (at the equator) as determined by different observers from the motions of sun-spots has remained constant during the past 80 years at 25.02 days, a value corresponding to a linear velocity of 2.02 km./sec. On the other hand, St. John has found from his observations with the 150-foot tower telescope, which began in 1914, values which decreased slowly, reaching a minimum of 1.90 km./sec. in 1923. Since 1928 the linear velocity has been increasing at a rate more rapid than the decrease, and is now nearing 2.00 km./sec. The earliest spectroscopic observations at Mount Wilson by Adams and Miss Lasby, in 1906-1908, gave a value of 2.06 km./sec.

The velocities of rotation show no trace of the sun-spot cycle of 11.2 years and, as yet, no definite evidence of the 22-year cycle within which the magnetic polarities of sun-spots reverse their signs in the two hemispheres. Such a reversal, corresponding to a reversal in the direction of whirl of the sun-spot vortices, might perhaps be expected to change the direction of equatorial drifts in the sun's atmosphere set up by the vortical motion.

Nicholson has made some spectroscopic observations of the effect of scattered light on measurements of solar rotation, and finds corrections of about 1.5 per cent to be applied to the photographs taken by the usual method at Mount Wilson.

#### INFRA-RED SOLAR SPECTRUM

With the exception of a short gap between  $\lambda 7750$  and  $\lambda 8050$ , Babcock has practically completed his measurements of the wave-lengths of solar lines in the region  $\lambda 7330$  to  $\lambda 9931$ . About 3200 lines have been measured, many of them on 20 or more spectrograms. A total of 1700 lines has been added to the Supplement to the Revision of Rowland's Table, 327 of which lie between  $\lambda 9931$  and  $\lambda 11634$ .

The final wave-lengths depend on about 250 standards, well distributed over the interval  $\lambda 7330$ - $\lambda 11204$ , whose relative values are probably correct to one part in two million. In terms of the red cadmium standard the accuracy is one part in one million. Out to  $\lambda 9000$  the provisional results have



been but little changed; from  $\lambda 9000$  to  $\lambda 9800$  the corrections are important, owing to a systematic error of 0.072 Å discovered in the scale of Brackett. Solar lines have been distinguished from those of telluric origin by means of solar rotation (to  $\lambda 9000$ ) and the difference shown by spectra of high sun and low sun ( $\lambda 9000$ – $\lambda 9900$ ).

#### ATMOSPHERIC BANDS IN SOLAR SPECTRUM

Babcock has completed the measurement of about 400 lines in the oxygen bands, important chiefly as a means of determining the masses of the oxygen isotopes. Some of the lines are also useful as standards, and certain groups of lines provide valuable tests of resolving power for large instruments. The range of intensity determined from the air path which renders them observable is about 1 to 100,000.

Babcock's data on some of the many hundred water vapor lines in the solar spectrum are being used by Giauque in an investigation of the bands of the water molecule. Promising signs of regularity have been discovered. Nine species of water molecules are theoretically possible, and doubtless several of these contribute to the complexity of the infra-red bands.

#### ULTRA-VIOLET SOLAR RADIATION

Daily measurements of the ratio of ultra-violet sunlight transmitted by silver ( $\lambda 0.32\mu$ ) to the green sunlight transmitted by gold ( $\lambda 0.5\mu$ ) have been continued by Pettit as in former years. The monthly averages are now somewhat lower than those observed in June 1924, which are taken as the unit. The highest was 1.57 in November 1925 and the lowest, 0.88 in April 1931. The yearly averages for the last nine years are shown in the accompanying table.

Year	Ratio	No. sun-spot groups daily	Year	Ratio	No. sun-spot groups daily
(1924).....	(1.09)	1.4	1929.....	1.26	6.0
1925.....	1.37	4.4	1930.....	1.22	3.9
1926.....	1.36	5.9	1931.....	1.07	2.3
1927.....	1.35	6.3	(1932).....	(1.00)	(1.5)
1928.....	1.23	6.3			

The data for 1924 and 1932 are incomplete: those for 1924 represent only 20 days between May 28 and October 2, all measures of good quality, however, and probably indicative of the value for the year. Probably no important increase in the yearly mean is to be expected until after the sun-spot minimum, which should occur within a year or two.

#### ULTRA-VIOLET LIMIT OF SKYLIGHT AND OF DIRECT SUNLIGHT

A series of exposures to direct sunlight and to northern skylight was made by Pettit at the solstices between 1928 and 1931 with two different spectrographs, each crossed with a Bausch and Lomb monochromator. The results show that in midsummer the ultra-violet limit of direct sunlight in Pasadena is  $\lambda 0.290\mu$ , and of skylight  $50^\circ$  above the northern horizon,  $\lambda 0.295\mu$ .



In midwinter the limits are  $\lambda 0.296\mu$  and  $\lambda 0.298\mu$ , respectively. One plate made with the quartz spectrograph gave  $\lambda 0.296\mu$  for skylight in midwinter. It thus appears that for a point far from the sun it would be difficult at any season to detect light of wave-length much less than  $\lambda 0.295\mu$ . This argues for a small amount of ozone in the lower atmosphere.

A direct determination of the ozone content follows from Pettit's measurement of the ultra-violet solar energy curve made at Tucson, Arizona, in the latter half of May 1931. A comparison of the observed and computed transmission coefficients gave for that station and date, and for normal pressure and temperature, a thickness of 0.18 cm. for the ozone layer.

## INVESTIGATIONS ON THE MOON, COMETS AND PLANETS

### MAP OF THE MOON

Preparations for the large-scale photographic map of the moon, as seen projected upon a 15-inch globe, were continued during the summer months of 1931 by Dr. F. E. Wright, Chairman of the Committee on the Study of the Surface Features of the Moon. The double-walled house, 140 feet in length, through which the beam of light from the lunar negative passes forward and backward between two concave mirrors, the globe and the photographic plate, has proved efficient in reducing air disturbances, and very fine detail is visible in the projected image. Some photographs were made, but a slight tremor, traced by Dr. Wright to ground radiation inside the house, affected the definition during the somewhat long exposures necessitated by the faintness of the light. This difficulty should be easily eliminated by covering the ground with suitable insulating material or a wooden floor. The investigation, which shows in an interesting way the sensitiveness of a horizontal beam of light 540 feet long to slight amounts of radiation, will be continued by Dr. Wright next year.

### COMETARY OBSERVATIONS

A search for Comet Neujmin (1913 III) by Nicholson and Miss Richmond in August and September 1931 resulted in the discovery of a sixteenth magnitude object, moving at approximately the predicted rate, not far from the position extrapolated from the ephemeris used in the search. The object showed no coma. The comet at the time of its discovery in 1913 generally presented a stellar appearance. It showed a slight coma only occasionally near perihelion, but never after it became as faint as sixteenth magnitude. Images of the comet on photographs taken from August to November gave corrected elements and a new ephemeris. On October 12 the comet's photographic magnitude was estimated at 17, the computed magnitude from Van Biesbroeck's formula being 16.6.

Five measurements of the position of Nagata's Comet were made by Nicholson on photographs obtained at Mount Wilson in July and August 1931.

### PLANETARY SPECTRA

The infra-red spectrum of Venus has been photographed by Adams and Dunham with a plane-grating spectrograph of 9 feet focal length at the coude focus of the 100-inch reflector. The spectrograms show clearly that

no lines of appreciable intensity corresponding to the terrestrial lines, either in the A band of oxygen at  $\lambda 7594$  or in the group of strong water vapor lines  $\lambda 8150$ – $\lambda 8300$ , are present in the spectrum of Venus. If oxygen or water vapor exists in appreciable quantities in the atmosphere of Venus, it must be at a level below that to which the spectroscopic observations penetrate.

A study of the photographs at once showed the presence in the spectrum of Venus at  $\lambda 7820$  and  $\lambda 7883$  of two bands sharply bounded toward the violet which do not appear in the sun. No laboratory identifications for these bands are available, but their structure is such as would be given by a linear molecule with simple P and R branches, the even lines being present in one branch and the odd in the other. On this assumption all the unblended lines can be represented closely by a quadratic formula, the constants of which lead to a moment of inertia for the lower state of the molecule concerned of  $70.5 \times 10^{-40}$  g. cm.<sup>2</sup>. This value is in excellent agreement with experimental determinations for carbon dioxide. If carbon dioxide is responsible for the observed bands, it is probable that they represent the eighth harmonic of the known band at  $4.3\mu$ . The seventh harmonic would be expected to occur near  $\lambda 8700$ , and a later photograph of the spectrum has, in fact, shown a band with its head at  $\lambda 8688$ , similar in structure to the other two.

In an attempt to confirm this identification, light passing twice through a pipe 20 meters long and filled with carbon dioxide has been photographed with a spectrograph similar to that used for the observations of Venus. With carbon dioxide at a pressure of 10 atmospheres and a 40-meter path, a faint line, agreeing closely with the position of the head of the band at  $\lambda 8688$ , appears in the spectrum. The bands at shorter wave-lengths have not as yet been observed.

Dunham has photographed with the 9-foot plane-grating spectrograph the well-known absorption bands in the spectrum of Jupiter. In this way he has resolved the band near  $\lambda 6460$  into a considerable number of separate lines. Since the image of Jupiter on the slit has a diameter of some 15 mm., the use of a cylindrical lens of short focal length in front of the plate makes it possible to reduce the exposure greatly and still leave the spectrum of measurable width. With a wide slit and cylindrical lens, spectra of Jupiter extending as far as  $\lambda 8800$  have been photographed in four hours. The definition is sufficient to show much detail. Spectra on a smaller scale have been obtained with the grating spectrograph at the Cassegrain focus. Dunham has measured a large number of individual lines in the bands near  $\lambda 7900$  and  $\lambda 8650$  and in a band not previously observed near  $\lambda 8400$ . A band of great intensity occurs near  $\lambda 8800$ . Their identification is now being studied.

## RESEARCHES ON NEBULÆ

### GENERAL SURVEYS

The survey of faint nebulae has been extended by Hubble to include zones in galactic latitudes  $\pm 35^\circ$ ,  $45^\circ$ ,  $55^\circ$ ,  $65^\circ$ ,  $75^\circ$  and  $85^\circ$ . The necessary plates have now been assembled, and the 6000 additional nebulae thus found strengthen the previous conclusions on nebular distribution without materially altering the numerical results.

The systematic photography, under uniform conditions, of all extra-galactic nebulae brighter than photographic magnitude 14 between declinations  $0^\circ$  and  $+15^\circ$  has been begun by Hubble. Forty plates have already been taken. The observations are part of a cooperative plan to obtain statistical data on the form, structure, classification and other features of nebulae.

#### CLUSTERS OF NEBULÆ

Several new clusters have been identified, and data on the general distribution of clusters are slowly accumulating. In the future, clusters will be designated by the names of the constellations in which they are situated, followed by a Roman numeral in case more than one occurs in the same constellation. A few of the more interesting new clusters are as follows:

Gemini,  $\alpha = 7^h 2^m$ ,  $\delta = +35^\circ 12'$ , 1900. Found by Hubble. About 150 nebulae in a circle  $40'$  in diameter, the brightest of the order of 17.5 pg. m.; estimated distance, 40 million parsecs; radial velocity, by Humason,  $+24,000$  km./sec.; galactic coordinates, approximately  $150^\circ$  and  $+20^\circ$ .

Andromeda,  $\alpha = 0^h 16^m 3$ ,  $\delta = +21^\circ 54'$ , 1900. Found by Baade. About 70 members, mostly within a circle  $25'$  in diameter. N.G.C. 80 and 83 appear to be the brightest members.

Leo II,  $\alpha = 11^h 21^m 9$ ,  $\delta = +17^\circ 40'$ , 1900. Found by Baade. A rich cluster including about 300 members brighter than the limit of the plates, about 19.0 pg. m., within a circle  $36'$  in diameter. The brightest nebulae are about 16.8 pg. m. A photometric study of this cluster and of Ursa Major II is under way by Baade.

Coma II,  $\alpha = 13^h 3^m 2$ ,  $\delta = +30^\circ 0'$ , 1900. Found by Baade. A cluster of very faint nebulae within a circle about  $8'$  in diameter. The brightest members appear to be approximately 19.0 pg. m. This is the faintest cluster known at present and is probably well beyond the limit to which nebulae in general can be satisfactorily studied with the 100-inch telescope.

#### PROPER MOTIONS IN SPIRAL NEBULÆ

Photographs of spiral nebulae for comparison with existing photographs over intervals of ten years or more have been made by van Maanen and Humason. Most of these are being taken at the Newtonian focus of the 100-inch reflector on Eastman 33 plates especially for the measurement of small displacements. Two pairs of plates of M 33 made at intervals of 11 and 13 years at the Cassegrain focus of the 60-inch reflector have been measured by van Maanen, and preliminary results have been obtained for a few others.

#### PHOTOMETRY OF NEBULÆ

Accurate total magnitudes and colors of about 40 nebulae have been determined by Stebbins with a photoelectric cell at the primary focus of the 100-inch reflector. The magnitudes (essentially equivalent to photographic magnitudes) were measured for each of a series of apertures having different diameters. The results show that the diameters of the nebulae are substantially larger than those estimated from direct photographs and that the extreme outer regions contribute appreciably to the total brightness. The



colors were derived from measures through blue and yellow filters. They exhibit a moderate range around a mean color class of about G8, whereas the mean spectral type is about G3. The photoelectric measures of nebulae will be continued by Stebbins and by Smith with the object of establishing a standard sequence of magnitudes.

The moving-plate camera (Schrafferkassette), which may be used either with the 100-inch reflector or with the 10-inch Cooke refractor, has proved well adapted to nebular photometry. Magnitudes derived from images about three times the size of the focal nebular images agree with those obtained with the photoelectric cell. Accurate results may be obtained to a limit of 18.0 pg. m. The instrument is being used to revise the magnitudes previously measured in clusters of nebulae.

#### SPECTRA OF NEBULÆ

Humason has obtained spectrograms of nebulae in three faint clusters whose brightest members are fainter than 17.0 pg. m. These spectra are difficult to interpret since they are necessarily narrow and the H and K lines are relatively inconspicuous. Four spectrograms of the two brightest members of the Gemini cluster indicate red-shifts corresponding to a velocity of +24,000 km./sec., a result believed to be reliable. Spectrograms of nebulae in two fainter clusters can not be interpreted with confidence, although they suggest still larger red-shifts.

Radial velocities have also been measured for N.G.C. 160, 5846, 7177, 278 and 404. A spectrogram of an object in M 31, tentatively identified by Hubble as an open cluster, indicates a spectral type of F0 and gives a negative velocity of the order to be expected for an object in the spiral.

#### NEBULOUS OBJECTS IN MESSIER 31

One hundred and forty nebulous objects associated with M 31 have been provisionally identified by Hubble as globular clusters. Photographic absolute magnitudes range from -4 to -7, diameters from about 4 to 16 parsecs. These objects appear to be systematically fainter than galactic globular clusters by 0.75 to 1.95 mag., according to the interpretation of the data. The two groups overlap to a considerable extent, however. The known globular clusters in the Magellanic Clouds are comparable with the brighter objects in M 31. Apparently similar objects are found in N.G.C. 6822, M 33, 81 and 101.

#### MISCELLANEOUS STELLAR INVESTIGATIONS

##### TRIGONOMETRIC PARALLAXES

In continuation of his work on trigonometric parallaxes, van Maanen has finished 22 fields during the year, including one Cepheid, UV Draconis, one planetary nebula, N.G.C. 6826, and 12 faint stars of large proper motion discovered by Max Wolf and by Ross. Of these, 11 have photographic absolute magnitudes fainter than +10. The most interesting cases are:

	P.M.	Abs. Parallax	Pg. M.
Ross 619	5".40	0".158	15.4
Ross 248	1.82	0.319	16.3



## PROPER MOTIONS

For the measurement of proper motions, van Maanen, assisted by Willis, has taken about 250 plates with the two reflectors. At least two first-epoch plates are now available for 126 Cepheids and for 65 spiral nebulae which have a stellar, or at least a measurable, nucleus and several measurable points in the arms.

The material for deriving corrections to Boss's proper motions and for determining the proper motions of the faint comparison stars used by van Maanen in his parallax and proper motion work has all been obtained. Willis has measured 2178 stars in 113 fields well distributed over the northern hemisphere for which the interval between the old and the new plates ranges from 10 to 18 years. Only eleven of the stars have relative motions exceeding  $0''.1$  per year. The average probable error for proper motions in right ascension or in declination is  $0''.0016$ . A preliminary result for the corrections to the motions in Boss's Catalogue is  $+0''.001$  in right ascension and  $+0''.011$  in declination.

## STELLAR INTERFEROMETERS

Strömberg has designed an interferometer for the measurement of the separations and position angles of double stars which is now under construction in the instrument shop. In principle it is similar to that used successfully for Capella but provides for the measurement of much larger separations, as much as five seconds of arc, it is hoped, under fair conditions of seeing. Two plane-parallel glass plates, through each of which a portion of the beam of light passes, can be turned in opposite directions about an axis perpendicular to the beam, thus making it possible to displace or to superimpose the interference patterns. With a second pair of slits, position angles can be measured. In the laboratory the errors of individual settings with such an instrument are of the order of 0.01 of a fringe.

Pease has made a few observations with the 50-foot interferometer, but no general program will be undertaken until after the completion of the investigation on the velocity of light. The section of the interferometer beam supporting the 40-inch concave mirror has been made more rigid by the addition of braces attached with fitted bolts.

## STELLAR PHOTOMETRY

Except for a few control photographs, the determination of photovisual magnitudes in 42 Selected Areas undertaken by Seares with the assistance of Miss Joyner is finished. Publication will be deferred, however, until certain tests involving exposure ratios, photoelectric magnitudes, and spectral types can be applied.

The moving-plate camera has been extensively used by Christie in connection with the 10-inch Cooke refractor for the observation of variables. Discussion of about 350 plates taken with this instrument shows an excellent degree of precision. Several Cepheids and the eclipsing variable TX Ursae Majoris are being followed photometrically in conjunction with spectroscopic observations by Joy. The variability of Boss 4351 and H.D. 198287-8, suspected from the character of their velocity curves and from visual estimates, has been confirmed.

As a means of standardizing observations of nebulae made with the photoelectric photometer installed last year at the coudé focus of the 60-inch telescope, Smith has begun the observation of a considerable number of stars in the Selected Areas having magnitudes between 10 and 15. Preliminary reductions show reasonably good agreement between the photoelectric measurements and the photographic and photovisual magnitudes determined by Seares.

Dr. Stebbins has used his photoelectric photometer in connection with the 100-inch telescope for the measurement of magnitudes and colors of faint stars. Good color indices may be obtained to a limit of 13.0 pg. m. The B-type stars fainter than 8.0 near the central line of the Milky Way show a color excess, presumably due to selective absorption, similar to that found for the brighter B stars from observations made at Madison.

A serious obstacle to the use of catalogues of stellar magnitude is the uncertainty as to their systematic relations to each other and to the international system. Seares has given the matter much attention and in preparing the report on stellar photometry for the 1932 meeting of the International Astronomical Union succeeded in determining the systematic corrections for nine catalogues of polar stars, six of photographic and three of visual or photovisual magnitude. The scale and color corrections, first established to a photographic limit of 8.0, have since been extended to about 10.0 for those catalogues which include fainter stars. With the aid of these results Seares and Miss Joyner are now preparing mean magnitudes for about 200 additional polar standards for use in studies of the brighter stars and in the standardization of catalogues not yet correlated with the international system.

#### GLOBULAR CLUSTERS

A detailed photometric study of N.G.C. 2419 has been begun by Baade with the 100-inch telescope. Judged by the brightness of its stars, the cluster is the most distant object of its class; it is also of interest because its position is nearly opposite that of the center of the galactic system, whereas most remote clusters appear in the general direction of the center. The 27 variables thus far discovered give a provisional distance of 72,000 parsecs, a result subject to revision since the possible influence of obscuration is still to be considered.

Fifteen new variables have been found in N.G.C. 7006 by Hubble, who is making a photometric study of the cluster.

Radial velocities for N.G.C. 6440, 6656, 6779, 6981 and 7006, whose spectra have hitherto been unobserved, have been derived by Humason. Magnitudes and colors of a selected list of globular clusters have been measured by Stebbins with the photoelectric cell. The color indices of several clusters in obscured regions are considerably larger than those of normal M stars, a result which suggests the influence of selective absorption. Photographic magnitudes are also being determined by Christie with the moving-plate camera attached to the 10-inch Cooke refractor.

#### STELLAR STATISTICS

The numerical method of determining the space density of stars developed by Seares has led to the conclusion that the luminosity function for all

spectral types together is not independent of distance. The indicated frequencies for high-luminosity stars near the sun are greater than the average, in harmony with the known spectral distribution of stars in the local cluster. Since the luminosity function is based on these near-by stars, it is not immediately applicable to stars at greater distances.

Data on proper motions and mean parallaxes of faint stars of magnitudes 13 to 17 collected by van Maanen and Willis are well represented by a mean parallax formula proposed by Seares in 1924. The significant detail, as also pointed out by van Maanen, is that the mean parallax of faint stars having moderate or large proper motions is nearly proportional to the proper motion and little dependent on the magnitude. This result in turn confirms a conclusion by Seares to the effect that the frequencies of low-luminosity stars continue to increase to at least the fourteenth absolute magnitude and fixes the space density of stars near the sun at a minimum of 9 or 10 stars per 100 cubic parsecs.

#### SIZE OF THE GALACTIC SYSTEM

The construction by Ellerman of a mosaic map of the Milky Way from photographs obtained mostly at Mount Wilson by Dr. Ross of the Yerkes Observatory with a 5-inch objective of his own design has led Seares to review the evidence bearing on the size of the galactic system relative to the great spiral nebulae. The map, which extends from Cygnus to the southern limit of Sagittarius, shows very effectively the relation of the obscuring clouds to the distribution of the globular clusters on which estimates of the size of the system depend. The great bulk of the clusters, including most of those to which great distances have been assigned, fall within the obscured region, which coincides closely with Hubble's zone of avoidance for the spiral nebulae. It seems likely that allowance for absorption will remove much of the 5 to 1 disparity in the dimensions of our own system and those of the Andromeda nebula, a conclusion strengthened by Stebbins's recent measures of the colors of clusters. There still remains, however, as far as can be judged at present, a large difference in mass. For a few remote objects, such as N.G.C. 7006, 2419 and 4147, which have always seemed to be somewhat isolated from the main body of clusters, there is little or no evidence of obscuration. It is not improbable that these clusters lie well beyond the limit of the stars belonging to our own system.

#### STELLAR SPECTROSCOPY

The stellar spectroscopic equipment has remained without radical change throughout the year. The three-prism spectrograph for work in the ultra-violet has been modified slightly to admit of more accurate photometric standardizing and is being used by Williams in studies of line-contours in early-type spectra. A three-prism instrument with dense glass prisms, used in conjunction with a 40-inch camera for high dispersion work on bright stars, has been partially completed. The plane-grating spectrograph at the Cassegrain focus of the 100-inch reflector has been employed extensively in the study of spectra in the red and infra-red regions.

At the coudé focus of the 100-inch reflector a plane grating in combination with the 9-foot collimator and camera lens has proved most useful in the



investigation of the spectra of planets and bright stars in the region  $\lambda 7600$ – $\lambda 8800$ . For fainter spectra a camera with a focal length of 40 inches may be attached to the same instrument. The 6-inch Ross lens of 15 feet focal length which is used for the larger spectrograph was found last year to be giving inferior definition. On examination one of the four component lenses proved to have a warped figure and has been corrected by Dalton in our optical shop. The large  $53^\circ$  prism of dense glass has also been refigured, and the definition of this instrument is now excellent. Both the 9-foot and the 15-foot spectrographs give almost exact theoretical resolution, as shown by tests with a compound microscope.

High-dispersion plates of stellar spectra have heretofore been calibrated in a separate grating spectrograph provided with a raster and a cylindrical lens. A more satisfactory method is that devised by Dunham which provides for photographing calibrating spectra simultaneously with the stellar exposure on each plate taken with the coudé spectrograph. Since a raster is not well adapted for use with a prism spectrograph, a step-slit has been adopted as the simplest and most reliable arrangement for producing a number of spectra of known intensity ratio. Sixteen steps are provided by rectangular openings, 0.2 to 6.0 mm. wide, in a slit plate mounted a little to one side of the tube carrying the main slit. The openings, which serve as calibrating slits, are placed end to end, in two groups separated by 10 mm., with their axes parallel to the main slit. Light from an evenly illuminated magnesium oxide screen entering the calibrating slits is directed by two small reflecting prisms to the collimating lens of the spectrograph. The calibrating spectra are formed in two series, with the stellar spectrum and the iron comparison between them. Their relative intensities vary in steps of  $10^{0.1}$ ; the absolute intensity can be controlled by varying the distance of the incandescent lamp from the diffusing screen. Suitable filters provide a distribution of intensity throughout the visible spectrum which is similar to that of a G0 star.

The total number of spectrograms obtained during the year with the spectrographs in regular use was 1269, of which 104 were with the coudé instruments and 65 with the small spectrograph and Rayton lens employed for nebulae and very faint stars. The observers have been Adams, Christie, Dunham, Humason, Joy, Lefèvre, Merrill, Sanford, Strömberg, Williams and Wilson.

#### RADIAL VELOCITIES

In continuation of the regular program the radial velocities of about 120 stars have been determined from three or more spectrograms. A star of unusually high velocity is Boss 5381, for which Christie finds a value of  $-196$  km./sec. Its spectral type is G5 and its absolute magnitude about  $+2.5$ .

Spectrographic observations of many variable stars are in progress. Joy is extending his study of Cepheid variables with low dispersion to stars of the thirteenth photographic magnitude and is studying the rotation of the galaxy with the aid of the radial velocities of the 102 Cepheids now available. Some of the faintest of these stars are at distances comparable with the estimated distance of the center of the galaxy (neglecting the effect of



space-absorption), and their mean distance, based upon the photographic period-luminosity relationship, is over 8000 light-years. Velocity curves have been derived by Sanford for the Cepheid variables Y Ophiuchi and FF Aquilæ from observations well distributed over all phases of the light variation. A fairly satisfactory velocity curve of U Monocerotis has also been constructed by Sanford from spectrograms obtained during 1931–1932. Observations extending as far back as 1920 provide interesting data regarding spectral changes and indicate a secular variation in velocity similar to that found in several other Cepheids.

Numerous Algol variables are under observation, including S Cancri, U Cephei and SX Cassiopeïæ by Joy, and TT Hydræ, AG Virginis, RW Comæ, TT Herculis and AK Herculis by Sanford. For several of these stars sufficient observations of radial velocity have been obtained to provide determinations of orbital elements.

Periods and approximate elements have been derived by Christie for the three spectroscopic binaries Boss 9, 283 and 4351. Of these, Boss 4351 has been found to show variations in light. Christie has also continued his investigation of the interesting star H.D. 198287–8, which appears to show a change of very long period in the amplitude of velocity variation, as well as in the motion of its center of mass. Miss MacCormack is calculating the orbit of the brighter component of Boss 35, an F-type spectroscopic binary discovered at Mount Wilson which shows double lines.

Among other radial velocity investigations, reference may be made to Sanford's measurements of N-type stars and Humason's work on stars in the Selected Areas; the study by Merrill of the detached D lines and by Sanford of the detached H and K lines in the spectra of selected B-type stars; and the measurements by Sanford, Adams and Miss MacCormack of the spectra of planets and bright stars taken with the coude spectrograph.

#### B-TYPE STARS WITH EMISSION LINES

The extensive program on these stars undertaken by Merrill, Humason and Miss Burwell, and brought to an end during the year, has consisted of two parts: (1) a spectroscopic survey of the northern Milky Way with the 10-inch telescope and objective-prism, using the region of the red hydrogen line H $\alpha$ ; (2) a detailed examination with slit spectrographs attached to the large reflectors of each new object showing bright H $\alpha$ . Part (2) was extended to include known stars with incomplete data. The entire investigation, already reported upon for the years 1919–1924, may be summarized as follows: 233 objects not previously known have been found to have one or more bright hydrogen lines; all except 11 are of type B or closely related classes; the spectral types, behavior of the hydrogen series, etc., have been determined for these and other similar stars, thus considerably extending the data desirable for statistical investigations; numerous stars have been found to exhibit peculiarities of physical interest which repay extended observation. Extension of this program to the southern Milky Way and the Magellanic Clouds would be of great interest.

The material for a catalogue and bibliography of all known bright-line stars of class B has been collected by Merrill and Miss Burwell and is now nearly ready for publication.

Observations of the complex Be spectrum of B. D. + 11°4673 have been continued by Merrill throughout one additional cycle of the 800-day period. The anomalous phase-displacements between the velocity curves of various elements, discovered by combining data from several cycles, are confirmed by this more nearly continuous series of observations during a single cycle.

Several B-type stars with bright lines have been discovered by Wilson in the course of an investigation of the relative intensities of detached  $D_1$  and  $D_2$  and of the absorption lines of hydrogen in stars of type B. For this work he is using panchromatic plates and the Cassegrain spectrograph on the 60-inch reflector. Intensities will be determined from microphotometer tracings.

#### FORBIDDEN LINES IN STELLAR SPECTRA

Merrill has found in the course of his study of Be stars several stars with spectra exhibiting lines associated with gaseous nebulae. A curious fact is that the chief nebular lines  $N_1$  and  $N_2$  are considerably fainter than other nebular lines. These objects appear to be intermediate between planetary nebulae and ordinary Be stars and are of interest not only in themselves but for the assistance they may provide in the physical study of forbidden lines. A faint Be star has also been discovered in whose spectrum the nebular lines  $\lambda\lambda 6300$  and  $6363$  (forbidden lines of neutral oxygen) are prominent in emission.

Observations by Joy in the summer of 1931 of the spectrum of the nova-like variable RT Serpentis showed that a marked change had taken place since 1928. Although the bright lines of hydrogen and helium remained unchanged, the bright enhanced lines of iron, most of which are due to forbidden transitions, had nearly disappeared, and the nebular lines  $\lambda\lambda 4363$ ,  $4658$ ,  $4686$ ,  $4701$ ,  $4733$  and  $5007$  had appeared in emission with considerable strength.

From recent studies of the atomic relationships of spectral lines, Merrill has found it possible to identify a bright band observed in the spectra of several novae by Wright and by Adams with the green auroral line  $\lambda 5577$  [O I].

#### INFRA-RED SPECTRUM OF $\alpha$ CYGNI

On a photograph taken with the small grating spectrograph in June 1932, Merrill has identified 14 members of the Paschen series of hydrogen from  $m = 11$  ( $\lambda 8863$ ) to  $m = 24$  ( $\lambda 8334$ ). Infra-red lines of O I and Ca II are outstanding, and numerous lines of N I have been recognized.

#### VARIABLE STARS WITH INTERMEDIATE PERIODS

The spectra of 45 variable stars with periods intermediate between those of the Cepheids and Mira stars of long period have been investigated by Joy. Twenty-three of these show spectra of types varying from G to K with bright hydrogen lines at certain phases and titanium bands at minimum. Velocity changes are small and irregular. Twenty-two stars have advanced M-type spectra (M5-M7) without emission lines; the spectra do not change with phase and velocity variations are uncertain. There seems to be no spectroscopic connecting link between these two groups. A study of the distribution of variables of intermediate period shows a wide dispersion in galactic latitude for stars of such high luminosity. Very few, how-

ever, are found between longitudes  $180^\circ$  and  $350^\circ$ . The dispersion in the radial velocities of these variables, as in those of the RR Lyræ stars, is very large as compared with that of the Cepheids.

An examination of 21 spectrograms of SX Herculis with a period of 102 days indicates that this star is in some respects intermediate between the Cepheids and the long-period variables. At maximum its spectrum is eG4e with bright hydrogen lines, but at minimum, hydrogen emission is replaced by absorption. The spectrum at minimum is G8 with titanium oxide bands superposed.

#### STARS WITH BRIGHT H AND K LINES

Observations of the H and K region in the spectra of stars of late type have been continued by Adams and Joy with the three-prism spectrograph of light flint prisms. With the dispersion used, the bright H and K lines in dwarfs appear as single, sharp lines, while in giants they are double, with the components separated by the absorption lines  $H_3$  and  $K_3$ , which vary in strength. The bright components  $H_2$  and  $K_2$  in giants are usually unsymmetrical, the red component being the stronger in most cases. In general, spectra of types earlier than G8 do not show bright lines. Preliminary results for 46 stars have been published.

#### ISOTOPE BANDS OF CARBON IN STELLAR SPECTRA

Sanford has found certain details in the spectra of stars of type R which are in excellent agreement with secondary heads to the main isotope bands at  $\lambda 4745$  ( $C^{12}C^{13}$  molecule) and  $\lambda 4752$  ( $C^{13}C^{13}$  molecule). Their wavelengths are  $\lambda 4723$  and  $\lambda 4731$ . They form a pair differing in wave-length from the main bands by the same amount that the known secondary at  $\lambda 4715$  differs from the main Swan band at  $\lambda 4737$ . If present at all in stars of type N, the lines  $\lambda 4715$ ,  $4723$  and  $4731$  are extremely faint, a result perhaps to be expected because of the lower temperature of stars of this type.

#### SOME ABNORMAL SPECTRA

Three anomalous stars have been found by Merrill in the spectra of which a bright line of ionized helium,  $\lambda 4686$ , is associated with absorption bands of titanium oxide. Their spectra are somewhat similar to that of Z Andromedæ described by H. H. Plaskett.

Observations of XX Ophiuchi by Merrill have shown that at the beginning and the end of the decade 1921–1931 the spectrum was marked by numerous emission lines of ionized iron in addition to those of hydrogen. In 1925, however, wide, displaced absorption lines, especially of ionized titanium, made their appearance. The star is a variable of the R Coronæ type, but the relationship of the spectroscopic changes to the light curve is unexpected and puzzling. Comparison of this spectrum with that of a nova suggests that a modification of the expanding-shell hypothesis might explain certain features.

#### CLASSIFICATION OF STARS IN THE SELECTED AREAS

Humason has completed the classification of the spectra of 4066 stars in Selected Areas 1 to 115 as far as photographic magnitude  $13.3 \pm$ . About 80 per cent are fainter than 11.0. The maximum frequency of stars of



photographic magnitudes  $11.0$  to  $13.3 \pm$  is found in type G (F4–G4), and the numbers of G stars increase with increasing magnitude and galactic latitude. In high galactic latitudes 68 per cent of the stars of magnitude 12.5 are of type G, a large majority probably being dwarfs at distances of 500 parsecs or less. In low galactic latitudes high frequencies are observed among A-type stars brighter than magnitude 9.5. Most of the stars of type B are concentrated in the region near Area 98, which includes 44 per cent of all the B stars observed.

#### SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX

With the completion of the reduction table for giant stars, revised to include the use of additional lines, Adams has applied the spectroscopic method to the determination of the absolute magnitudes of about 4000 stars. These include dwarfs and giants of types ranging from A to M. In addition to showing very clearly the division of stars of types G and later into dwarfs, giants and supergiants, with few or no intermediate stars between dwarfs and giants, the study of this large amount of material leads to the following conclusions:

1. In each class, with the possible exception of the supergiants, the absolute magnitude shows a nearly linear progression with spectral type except among the stars of type M. Among the giants the brightness increases with advancing spectral type, increase in size more than counteracting decrease in surface brightness. Among the dwarfs the brightness decreases uniformly to type M0 and then very rapidly to later subdivisions.

2. The striking absence of normal giants in types F5 to G0 is due to the fact that nearly all luminous stars of these types are supergiants. The curve of the dwarf stars, or those belonging to the main sequence, crosses the curve of normal giants at about type F0, and most A-type stars have absolute magnitudes around  $+2.0$ . Among stars earlier than type A the more luminous should belong to the main sequence.

3. Both giant and dwarf stars, but especially the giants, show a strong tendency to group around definite values of absolute magnitude. About 90 per cent of the K0 giants fall within limits of one magnitude, or a range of 2.5 times in the amount of light they give out.

4. Direct comparisons of the spectroscopic parallaxes with the trigonometric parallaxes of 1006 stars listed in Schlesinger's *Catalogue* show a mean difference of  $0.0004$ , the trigonometric values being the larger. With the possible exception of some A-type stars and supergiants, the agreement with Strömberg's absolute magnitudes derived by statistical methods is also good.

During the year Strömberg has completed his determination of the distribution of absolute magnitudes among stars apparently brighter than magnitude 6.0 and of spectral types M, K, G, F, A and B. The method is based on the observed distributions of reduced parallactic and peculiar motions and of radial velocities.

The results show a continuous change in the luminosity curve from type to type and thus strengthen the belief that the maxima and minima found are real. Five lines of maxima run through the spectral sequence. The



corresponding groups of stars may be designated by the terms supergiants, bright giants, normal giants, faint giants, and main sequence stars, which include the dwarfs. Between the M and the B stars the supergiants increase in brightness from absolute magnitude about  $-4$  to  $-6$ , and the bright giants from  $-2$  to  $-4$ . The normal giants have an absolute magnitude about  $0$  among M and K stars, decrease in brightness to about  $+1$  for type F, and increase again to about  $0$  for the B stars. The faint giants decrease in brightness from  $+2$  for the late K stars to  $+3.5$  for the F stars. The main sequence stars increase steadily in brightness from  $+7$  for the late K stars to  $-3$  for the early B stars and cross the branch of normal giants at type A, for which the common absolute magnitude is  $+1$ .

Two gaps exist in the frequency diagram. One corresponds to the deficiency among spectral types K and M of stars intermediate in brightness between giants and dwarfs. The other gap extends from spectral type G to B3 and indicates a separation of the bright giants from the normal giants and main sequence stars. There is reason to believe that this gap corresponds to a state in stellar constitution associated with Cepheid variation.

Strömberg has also started an investigation of the distribution of absolute magnitudes obtained from trigonometric parallaxes of stars brighter than apparent magnitude 5.5. The method depends on the numerical solution of an integral equation involving the distribution of measured parallaxes, apparent magnitudes and errors of measurement.

#### STELLAR SPECTROPHOTOMETRY

Designs of the equipment necessary for measurements of spectral energy with a radiometer at the coudé focus of the 100-inch reflector have been carried on by Smith. Various modifications of the apparatus have been investigated in the hope that the total energy falling within a given spectral range might be made independent of the seeing. Color screens having narrow transmission bands are available for only a few regions of the spectrum, and attempts to use the principle of the Abbe refractometer have proved impractical because of the great demands upon the optical system and the excessive loss of light. The present plan is to use a spectrometer and attempt to eliminate the effects of seeing by the method developed by Smith last year to overcome the Brownian movement. If the seeing, averaged over a one- or two-minute interval, remains fairly constant for as long as an hour, the method should prove satisfactory.

#### MICROPHOTOMETERS

Three microphotometers, each using a different sensitive element, are now available for the study of photographs of solar and stellar spectra. The first is the large instrument designed by Dr. Koch which uses a thermocouple and galvanometer and is now employed chiefly in work upon the contours of solar lines. A second instrument completed during the year was designed by Smith and utilizes a radiometer. It has proved satisfactory in performance and many tracings of stellar spectra have been obtained with it. At present Wilson is employing this instrument in an investigation of the spectrum of Nova Aquilæ, using the calibration method suggested by Hogg based upon theoretical multiplet intensities of the comparison lines.

The third microphotometer is of the photoelectric type and uses an amplifier which has been found to be entirely reliable and very steady. Through the work of Dunham many improvements have been made, including a reduction in the period of the galvanometer to 0.1 second. Bromide paper records 50 cm. long can be made in one minute provided the magnification ratio between plate and record is not less than 1 to 40. Coordinates in both directions are photographed simultaneously on the record. The sensitivity is sufficient to give a full scale deflection with a first slit 0.001 mm. wide and 0.5 mm. long, and the resolution is such that when a knife-edge travels across a narrow beam 90 per cent of the deflection of the galvanometer occurs within 0.007 mm. This instrument is being used for both solar and stellar spectra, but more especially for the analysis of high-dispersion spectra of Cepheid variables and other stars by Dunham and Lefèvre.

A special study of the spectral energy distribution of early-type stars, particularly such as have abnormally high color indices, has been undertaken by Williams with the 3-prism ultra-violet spectrograph. The slit is kept vertical during the exposures by rotating the instrument in order that errors due to atmospheric dispersion may be avoided. Calibration spectra are recorded by a step-slit illuminated by an incandescent lamp provided with a blue filter. The contours of a number of absorption lines in the spectra of these stars have been measured for the purpose of deriving ionization temperatures.

#### IONIZATION IN STELLAR ATMOSPHERES

Dr. Russell has studied the progress of ionization in stellar atmospheres of various temperatures and pressures and the relation between opacity formulæ and the intensities of observable lines. The results are decisively in favor of the conclusion that the opacity arises mainly from the interaction of ions and free electrons and that the atmosphere consists mainly of hydrogen. At temperatures below 8000° C. the interplay of various factors leaves the whole amount of matter above the photosphere nearly constant with varying temperature, although not with varying gravity. When the hydrogen becomes ionized the opacity increases greatly and the atmosphere becomes much less extensive; in other words, the photosphere rises. This accounts for the weakening of lines of Fe II and similar elements as we pass from type F5 to type B9. If the atmospheres were of uniform depth, these lines would strengthen.

#### LABORATORY INVESTIGATIONS

##### RARE-EARTH SPECTRA

In continuation of his work on neodymium, King has classified according to temperature over 2600 lines between  $\lambda 2900$  and  $\lambda 7000$ , including about 850 of the stronger enhanced lines. The neodymium lines occurring in celestial spectra are among these enhanced lines. With the assistance of Miss Brayton, wave-lengths have been measured for about 1750 lines, many of which are lines of the neutral atoms previously unidentified.

Two hundred and eighty lines of doubly ionized cerium, a few possibly of the trebly ionized atoms, occurring in the interval  $\lambda 2167$ – $\lambda 3544$  in a

highly condensed spark have also been measured, in large part by R. B. King.

The furnace spectrum of europium has been extended toward the red, and progress has been made in the selection of lines of thulium in mixed spectra.

#### SPECTRUM AND NUCLEAR MOMENT OF RHENIUM

In a joint study of the rare element rhenium, King has examined the furnace spectrum from  $\lambda 2500$  to  $\lambda 6700$ , while Dr. Meggers, assisted by Mr. C. G. Peters, both of the Bureau of Standards, has photographed the arc spectrum under high dispersion from  $\lambda 3000$  to  $\lambda 6800$  with the object of resolving the hyperfine structure previously noted by Meggers as present in a majority of the lines. On account of the high melting point of rhenium, only 19 lines appeared in the furnace, but their intensities confirm the levels assumed in Meggers' analysis. From the spacing of the hyperfine components measured on both the furnace spectra and the arc spectrograms, Meggers, King and R. F. Bacher find the nuclear moment of rhenium to be  $2.5h/2\pi$  for both isotopes, which have mass numbers 185 and 187.

#### SPECTRA OF OTHER METALS

Completion of a study of the furnace spectrum of tungsten by King has yielded a list of 75 lines between  $\lambda 2800$  and  $\lambda 6700$ . While but a small fraction of the arc lines of tungsten, this list is sufficient for the selection of the lines of low energy-level.

Tantalum, also of high melting-point, was examined in the arc and spark, especially for the selection of enhanced lines. The spectrograms show that many tantalum lines possess hyperfine structure, a feature not previously observed.

The spectrum of columbium has been observed by Dr. Meggers with the third order of the 75-foot spectrograph on Mount Wilson and the fifth order of the 30-foot instrument in the laboratory. Even with the large scale thus obtained, the closeness of the patterns prevented full resolution of the hyperfine structure; nevertheless, improved data were obtained. The spectrograms, together with plates of the arc and spark spectra supplied by King, are being measured by Dr. Meggers at the Bureau of Standards. The hyperfine structure of lanthanum lines, which also proved too close for full resolution, was examined by Meggers.

#### IONIZATION IN FURNACE SPECTRA

The relative persistence in furnace spectra of lines belonging to the neutral and to the singly ionized atom has been observed by King. The effect of large differences in the abundance of the atoms was studied for calcium, strontium, barium and neodymium, the temperature and pressure remaining unchanged. At low concentration, the enhanced lines were found to be more persistent than the arc lines, only the more sensitive of which appeared at all. The probable explanation is that as the abundance is reduced, the opportunities for recombination of ionized atoms with free electrons become steadily less; with more vapor present, the atoms can change freely into the neutral state. The phenomena observed agree with the known strength of enhanced lines in the highly rarefied vapors in the



solar chromosphere, in giant stars and in nebulae. They may also explain why the rare earths, whose abundance in the sun is probably very low, show only enhanced lines in the solar spectrum.

#### ZEEMAN EFFECT

The construction of new, water-cooled coils for the large Weiss magnet opened the way for a resumption of the study of the magnetic resolution of spectrum lines. Spectrograms of cobalt by King giving the transverse Zeeman effect from  $\lambda 4100$  to  $\lambda 6900$  show the improved operation of the magnet and furnish material for comparison with the separation of cobalt lines in sun-spots and also for an analysis of the spectrum.

#### STUDY OF MAGNETOSTRICTION WITH THE SOLENOID MAGNET

The coreless solenoid magnet, which has been out of commission for several years owing to the use of the cooling chamber for the Michelson ether-drift experiment, has been prepared for service by a complete reconstruction of the cooling system and a rewinding of the magnet. Its first use has been in a cooperative investigation of the phenomena of diamagnetism conducted by Professor Goetz of the California Institute of Technology. With the aid of the magnet Mr. A. Wolf of that institution has studied magnetostriction in single crystals of bismuth under conditions permitting the detection of changes of one part in a hundred million in length of the crystal. With a field of 26,000 gauss the magnetostriction in pure bismuth crystals was found to be about one part in five million, in substantial agreement with recent results by Kapitza based on measurements in a transient field of 50,000 to 300,000 gauss. The change in length varies roughly as the square of the field, at least up to 26,000 gauss. This fact explains why the several investigators working with fields of 2000 to 3000 gauss failed even to observe the effect.

#### HIGH-CURRENT VACUUM TUBE

Anderson has completed a preliminary determination of the energy distribution in the continuous spectrum of the high-current vacuum tube between  $\lambda 8000$  and  $\lambda 3400$ . For the region  $\lambda 8000$  to  $\lambda 4000$  the shape of the energy curve is nearly that of a black body at  $10,000^\circ \text{K.}$ ; the intensity of the radiation, however, is 14 times that emitted by a black body at that temperature. In other words, the color temperature for the interval  $\lambda 8000$  to  $\lambda 4000$  is  $10,000^\circ \text{K.}$ , while the radiation temperature is very much higher, ranging from approximately  $60,000^\circ \text{K.}$  at  $\lambda 8000$  to  $28,000^\circ \text{K.}$  at  $\lambda 4000$ . It is planned to repeat and extend these observations with improved apparatus. Meanwhile Anderson is devoting his time to the 10-foot vacuum spectrograph, recently built in the instrument shop. This has still to be adjusted and made vacuum-tight.

#### LIMIT TO THE SENSITIVITY OF THE PHOTOELECTRIC CELL

An investigation of the general characteristics of photoelectric cells by Smith shows that their sensitivity is limited by the fluctuation in the number of photoelectrons produced by a given number of quanta. An evaluation of the probability function involved fixes the limit and indicates



that the photometer now in use with the 60-inch telescope reaches the theoretical value. Unless some device more sensitive than the present photoelectric cell is developed, improvement in the sensitivity of stellar photometers is therefore not to be expected.

#### RED-SENSITIVE PHOTOELECTRIC CELLS

The properties of a specially constructed caesium oxide photoelectric cell kindly supplied by Dr. Arnold of the Bell Telephone Laboratories have been investigated by Smith. The results indicate that the high red-sensitivity of this type of cell will make it especially useful for stellar photometry. The one disadvantage of a very high apparent dark current, which results from thermionic emission at ordinary temperatures, may be obviated by cooling the cell. Suitable means for cooling have been worked out, and it is planned to mount one of these cells in a small portable photometer which will also include a blue-sensitive potassium hydride cell. Since the maxima of spectral sensitivity for these cells are separated by about 3500 Å, the combination should furnish an exceedingly sensitive instrument for the determination of color indices.

#### THE GEIGER-MÜLLER COUNTER

Experiments by Smith in the physical laboratory and by Dr. G. L. Locher at the Rice Institute to test the possibilities of a Geiger-Müller counter for astronomical photometry indicate that the sensitivity can be pushed well into the visible spectrum and the speed of counting greatly increased. A type of counter consisting of a hollow half-cylinder and a fine wire supported nearly in the axis of the cylinder operates quite as well as the usual form. One of these new counters will be compared with a sensitive photoelectric photometer under actual observing conditions at the telescope.

#### ABSORPTION-LINE CONTOURS

The contours of the D lines of sodium in absorption have been studied by Korff with the 30-foot spectrograph. Contours are found to agree with classical (radiation damping) theory, and also with the new quantum mechanical theory of Weisskopf and Wigner. The widths of the lines vary as the square root of the number of atoms in the line of sight, and show an inverse-square variation of opacity with the wave-length distance from resonance. The 2:1 ratio of the D lines was found to hold with accuracy. The experiment determines a constant which involves  $e^2/m$  and hence yields an independent value of this ratio, namely,  $(2.51 \pm 0.2) \times 10^8$ , for which the accepted value is  $2.512 \times 10^8$ . The effect of foreign gases on the widths and the effective interaction-radii of the sodium-hydrogen and sodium-helium combinations has also been investigated. A 2.5-meter column of sodium vapor, longer than any hitherto used, has been employed to give an approach to astrophysical conditions.

#### RULING MACHINES

Under Babcock's direction numerous adjustments and improvements have been made in the old ruling machine. Four 6-inch, two 4-inch and three 2-inch gratings have been ruled. In addition, the machine has been used for numerous tests involving special rulings ranging from 625 to 92,000

lines per inch. Trials of certain steel alloys as substitutes for speculum metal have indicated directions in which further improvements should be sought.

A microscope fitted with vertical illuminator is a valuable addition to the equipment, particularly useful for adjusting the ruling diamond and for studying the characteristics of surfaces used for ruling.

The assembly of the new machine, designed to rule gratings up to 10 inches, is now nearly complete. The end thrust-bearing of the main screw, consisting of steel against diamond, is the principal feature still under construction. The machine is now ready for a series of rigorous optical tests of adjustment.

#### VELOCITY OF LIGHT

Measurements of the velocity of light were resumed by Pease and Pearson in April and will be continued until August when the investigation will finally be concluded. The air-tight connections between the 60-foot sections of 36-inch pipe which form the mile-long pipe-line were found to be in excellent condition after the long period of disuse, and few repairs were necessary. After the air-pumps had been readjusted, the pressure inside the pipe-line could be reduced to 2 to 3 mm. of mercury and maintained over long intervals of time. The length of the optical path was remeasured in January by Lieutenant E. B. Latham of the United States Coast and Geodetic Survey so that two independent determinations are now available.

The optical system has remained without change except for resilvering of the mirrors, and all measures have been made over an 8-mile path with the 32-sided rotating mirror. The observations have for the most part been carried on during a few hours in the evening when temperature conditions are most favorable. At other times a very slight change in the figure of the large mirrors distorts the image and finally spreads the light out so greatly that no measures can be made.

The results so far obtained are in good agreement with those of last year. A total of 10 to 12 series of measures, each consisting of about 50 sets of 10 individual settings, will be available for final reduction and discussion. A well-defined periodic variation of small amplitude seems to be present in the results, the origin of which is as yet unknown. Differential measurements of the length of optical path, and careful tests of the speed of the rotating mirror are being made at frequent intervals.

#### CONSTRUCTION DIVISION

The detailed work of the design of instruments has been under the charge of E. C. Nichols, assisted by H. S. Kinney. Alden F. Ayers has directed the work of the instrument shop and John S. Dalton has continued the construction of optical apparatus. Clement Jacomini, instrument maker, and George D. Jones, superintendent of building construction, both of whom have been associated with the Observatory since its beginning, retired from its service during the year. A. N. Beebe has carried on the work of general construction and maintenance.

Among the principal instruments built during the year have been the new ruling machine, the double-star interferometer, a new focal-plane

spectrograph for the 60-inch reflector, and a spectrometer for use with the radiometer at the 100-inch telescope. Apparatus for the solar eclipse of August 1932, the reconstruction of the Weiss magnet with a cooling coil for the solenoid magnet, and equipment for the investigation of the velocity of light have required much time in the instrument shop.

Little new construction has been carried on, but the buildings and instruments on Mount Wilson and in Pasadena and the transportation equipment have been maintained in excellent operating condition.

#### THE LIBRARY

The number of bound volumes in the library was increased by 726 volumes during the year and now amounts to 11,939. In addition, the library has 8500 pamphlets. The serial publications received number 143, of which 64 were by gift or exchange. In addition, the library receives the publications of about 200 observatories and research institutions.





## NUTRITION LABORATORY<sup>1</sup>

FRANCIS G. BENEDICT, DIRECTOR

The outside pressure upon the Nutrition Laboratory for the development and perfection of its special techniques has been somewhat lessened in recent years, hence making it possible to continue with long-planned researches in the field of comparative physiology. Our studies on the energy relationships of birds, particularly with reference to the minimum or basal requirements, have now been extended to include birds ranging in size from 20-gram canaries, sparrows, and parrakeets to a 17-kg. cassowary. With mammals metabolism measurements have been made on animals varying in weight from the 20-gram mouse to large domestic animals such as cows, steers, and horses weighing as much as 700 kg. Cold-blooded animals have also been studied, including 1-kg. lizards, snakes weighing from 2.5 to 32 kg., and great land tortoises, of which one specimen weighed 132 kg. Thus a large amount of data is available enabling a comparison of the basal metabolism of different species of animals. A comprehensive summarization and an analysis of the results of these various researches are at present being made.

Although the smallest mammals and birds have now been studied, there still remain numerous larger wild animals concerning which data will be earnestly sought in the near future. Unfortunately these animals can be studied only in captivity, after man has superimposed his notions of feeding upon them. But at least many important problems will be illuminated by such data. The unfailing cooperation that the Nutrition Laboratory has received from the New York Zoological Park and our intimate connections with the Carl Hagenbeck Tierpark in Hamburg, Germany, through their Scientific Director, Dr. L. Zukowsky, and their American representative, Mr. Joseph Benson of Nashua, New Hampshire, whose scientific interest is most keen, lead us to believe that the problem of studying such animals in captivity is by no means insuperable. As noted later, active research with the colony of *Macacus rhesus* in the Department of Embryology of the Carnegie Institution of Washington, Baltimore, has already begun. Plans for extending this study to include the large chimpanzee colony at the Anthropoid Experiment Station of Yale University, located at Orange Park, Florida, under the direction of Dr. Robert M. Yerkes, and the logical step of establishing connections with the winter quarters of some of the larger menageries and circuses all seem feasible. Doubtless these plans will materialize in the near future.

With each group of animals there is some special factor that can be investigated, such as the character of the diet; vegetable *versus* meat; high and low protein; scant and liberal feedings (the latter exemplified in the beef steer, the fattened goose, and the hog); and different degrees of muscular activity, illustrated by the almost immobile snake and the sloth, and the excessively active birds. Likewise there should be studies on the influence of light and dark upon nocturnal and diurnal animals; the influ-

<sup>1</sup> Situated in Boston, Massachusetts.

ence of differences in configuration as typified, for example, by the giraffe and the mouse; and the effects of the nature of the skin covering, such as the feathers of birds, the short hair of certain dogs, the long, heavy wool of sheep, and the hairless skins of animals like the rhinoceros, the hippopotamus and the elephant. These factors normally occurring in certain species of animals find their counterpart in normal and pathological conditions of humans. It is believed that information regarding the energy relationships in these various animals, especially the warm-blooded animals having body temperatures essentially that of man, should throw light upon the problems concerned with the vital activity of man.

#### COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, is still carrying on the cooperative investigations with the Nutrition Laboratory on the physiology of large domestic animals, with special reference to the metabolism of cows, horses and sows. Director John C. Kendall and President E. M. Lewis have continued their enthusiastic support of this most efficient cooperative venture.

Dr. Oscar Riddle, of the Department of Genetics of the Carnegie Institution of Washington, has accumulated further data on the basal metabolism of pigeons and doves.

Dr. Morris Steggerda has collected, for analysis at the Nutrition Laboratory, a number of food samples typical of the diet of the Maya Indians.

Dr. Walter Landauer, of Storrs Agricultural Experiment Station, Storrs, Connecticut, cooperated with the Nutrition Laboratory in a study of the physiology of normal and Frizzle fowl.

Dr. Kathryn Horst assisted in the preparation for publication of the results of the cooperative rat experiments carried out at Yale University with Professor L. B. Mendel.

Mrs. Mary Henderson Meyer was most helpful in assisting in a series of basal metabolism measurements on elderly women at the Massachusetts Home, and on American-born Chinese girls at Denison House in Boston.

Among the active workers continuing cooperative investigations in the Nutrition Laboratory's racial program Professor Eleanor D. Mason, of the Women's Christian College, Madras, India, has laid emphasis this year upon the influence of sleep, and high and low protein diets upon the basal metabolism of South Indian Women, and of the influence of acclimatization upon the metabolism of white women. At Yenching University, Peiping, China, Professor Stanley D. Wilson, in spite of many difficulties, has been successful in obtaining basal metabolism measurements on Chinese and is endeavoring to secure the cooperation of some Chinese eunuchs. Professor L. G. Kilborn is continuing his observations in West China Union University, Chengtu, Szechwan, China, and Professor H. S. D. Garven is still collecting data at Moukden Medical College, Moukden, Manchuria. Professor Carey D. Miller, of the Department of Household Science, University of Hawaii, Honolulu, is likewise continuing her studies, laying special emphasis upon the several racial mixtures so predominant in Hawaii.

A visit from Professor J. Giaja of Belgrade, Yugoslavia, whose own researches are of special importance to us, was greatly appreciated as was that from Dr. H. G. Earle of the Henry Lester Institute of Medical Research, Shanghai.

The Nutrition Laboratory has kept in close touch with the metabolism laboratory of Dr. C. G. L. Wolf of Addenbrooke's Hospital, Cambridge, England, and to facilitate the introduction of metabolism measurements as routine hospital procedure certain apparatus has been presented to the Addenbrooke's Hospital for Dr. Wolf's use.

### LECTURES

On February 14, 1932, Dr. T. M. Carpenter lectured on "Alcohol" in one of the Sunday afternoon series of popular medical lectures given annually at the Harvard Medical School.

On January 20, 1932, the Director addressed the Biological Institute at Harvard University on "Body Surface Area as a Problem in Biological Energetics." At a meeting of the Harvard Medical Society, held at the Peter Bent Brigham Hospital in Boston on March 8, 1932, a lecture was given on "Giant Tortoises and Pythons and their Contribution to Physiology."

### INVESTIGATIONS IN PROGRESS

*Gas-analysis apparatus*—Dr. Carpenter has modified his extraordinarily exact gas-analysis apparatus by eliminating all rubber joints but two; by installing a motor for operating the circulation pump of the potassium pyrogallate pipette and for operating a reciprocating pump for compressed air; and by mounting the glass parts and accessories on an aluminum frame, which gives greater rigidity and does not warp.

*Electrical compensation calorimeter*—This instrument has been used in a number of researches, but the intricacies of direct calorimetry are very great, and because of new emphasis laid upon the apportionment of the total heat-loss between that lost by radiation and conduction and that lost by vaporization of water, certain changes were necessitated in the apparatus. These have been introduced by V. Coropatchinsky, and exact control tests have been made, which prove that the apparatus is extremely satisfactory.

*Basal metabolism of very small birds and animals*—To further the investigations in the field of comparative physiology, basal metabolism measurements were made on normal (albino) and hairless mice, on canaries, parakeets and sparrows. Special attention was given to establishing the critical temperature for each of these animals and to studying the effect of widely different environmental temperatures upon the basal metabolism, and the influence of huddling or grouping together. A few rectal temperature observations were made with the mice, the canaries and the parakeets. The mice were kindly loaned or given to us by Dr. J. W. Schereschewsky and Dr. M. O. Lee of the Harvard Medical School and Dr. W. E. Castle of the Bussey Institution. Dr. J. E. Davis, of the University of Chicago, who had reported some unusually low basal values with mice, kindly sent us eight of his mice so that we might compare our results on his mice with



his own data. The experiments with small animals were carried out with the assistance of E. L. Fox, V. Coropatchinsky, and B. James.

*Influence of ingestion of sugars upon the respiratory exchange of mice and canaries*—Studies on the effect of the ingestion of sugars on the respiratory exchange of animals, which were begun last year, have been continued. Additional observations have been made on canaries, and experiments have been made with mice. The results are so different from those obtained with human subjects that it is planned to extend the work to include other animals. The experiments have been carried out by Dr. Carpenter, assisted by R. C. Lee, G. Lee, and Miss M. Burdett.

*Physiology of normal, moulting and Frizzle fowl*—Supplementing the earlier measurements made in 1919 and the later measurements made in 1930 on the respiratory exchange of normal hens, an extensive series of observations has been carried out on normal, moulting, and Frizzle hens and cocks. The research has included observations on the influence upon the basal respiratory exchange of different environmental temperatures, time of day and sex, and especially the effects of the defective plumage of the Frizzles upon the heat production and the vaporization of water. Surface temperature measurements were made on the comb, wattles, ear lobe, legs and feet as well as over the feathers on the breast and back of normal and Frizzle birds. These observations were in charge of E. L. Fox, who was assisted by V. Coropatchinsky and B. James. Dr. Walter Landauer, of Storrs Agricultural Experiment Station, who kindly lent us the fowl, cooperated in this investigation by subsidiary observations made at Storrs.

*Basal metabolism of the monkey (*Macacus rhesus*)*—During the fall of 1931, a respiration chamber suitable for studying the metabolism of monkeys was developed at the Nutrition Laboratory, thoroughly tested by E. L. Fox and R. C. Lee, and subsequently shipped to Baltimore for use in a cooperative investigation which has been undertaken with Dr. George L. Streeter, of the Department of Embryology of the Carnegie Institution of Washington. Miss Madeleine T. Skirven was trained at the Nutrition Laboratory in the use of this respiration chamber and the Carpenter gas-analysis apparatus, which is an essential part of the apparatus. Since the installation of the equipment in Baltimore, a large part of the time has been devoted to orientation experiments, which make it evident that with the monkey the strictly basal metabolism can be determined only in observations made at night, when the monkey is least active. The technique for basal measurements has now been perfected and we are in a position to study the various phases of the monkey's metabolism.

*Effect of hibernation upon metabolism of the woodchuck*—As a result of our research on cold-blooded animals and the comparisons derived therefrom with warm-blooded animals, it became desirable to study a hibernating animal, which represents, so to speak, one of the intermediary stages between the cold- and the warm-blooded species. Long series of observations have been made with two woodchucks both before, during, and following winter sleep. E. L. Fox had charge of these measurements, assisted by B. James.



*Metabolism of the goose*—The goose still remains one of the most important laboratory animals for study of excess feeding of most kinds of food materials. Its ability to stand very long fasts without damage, its ability to consume extremely large amounts of food, and its generally tractable nature make it an ideal laboratory animal. With the improved electrical compensation calorimeter a study of the relationship between the carbon-dioxide production, oxygen consumption, and total heat production, including observations on the vaporization of water and the rectal temperature, gives a very complete picture of the metabolic processes of this bird under various conditions of feeding. The experiments were in the hands of V. Coropatchinsky, assisted by E. L. Fox and B. James.

*Skin-area measurements of animals*—In connection with the Nutrition Laboratory's proposed summarization and analysis of the basal metabolism data for different animals, the skin areas of a rat, 15 mice, 4 guinea-pigs, one woodchuck and 6 monkeys, were directly measured by E. L. Fox, who was instructed by Dr. M. O. Lee of the Harvard Medical School in the use of his technique.

*Metabolism of pigeons and doves*—The cooperative research with Dr. Oscar Riddle, of the Department of Genetics of the Carnegie Institution of Washington, at Cold Spring Harbor (assisted by Mrs. G. C. Smith), has been continued to include observations on the effects of season, the endocrine glands and the environmental temperature in any given season upon the metabolism of pigeons and doves. The metabolism during growth in the common pigeon and the basal metabolism of the mourning dove and some of its hybrids have likewise been investigated.

*Metabolism of large domestic animals*—This past winter Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at Durham, New Hampshire, has carried out ten experiments on cows, each consisting of metabolism measurements during 2 days when the cows were on feed and 2 days after they had been fasting for from one to 3 days. One experiment of similar type was also made with 2 full-grown Berkshire sows. In addition, four experiments with 3 horses have been made during feeding with hay and grain or with grass and grain, and after fasting for from 2 to 5 days. The device for separate collection of feces and urine from cows, developed by Professor Ritzman, has been further perfected. In these investigations Professor Ritzman has been assisted by Mrs. H. H. Latimer, A. D. Littlehale, and N. F. Colovos.

*Helmet-rotamesser respiration apparatus for rapid orientation in basal metabolism measurements on humans*—In the belief that basal metabolism measurements should eventually become a routine procedure in the physical examination of all patients upon entrance into the hospital and that the respiration apparatus employed for such measurements should be so simplified as not to prove formidable to the patient, the Nutrition Laboratory has continued its tests with the helmet-rotamesser technique mentioned in the report of 1930-1931. It has been demonstrated that with this apparatus the clinician may know, within 15 minutes, the basal metabolism of the entering patient with an accuracy of  $\pm 5$  per cent. This makes routine metabolism measurements thoroughly practicable for all entering patients. E. L. Fox and R. C. Lee assisted in the control tests of this apparatus.

*Day to day variation in human basal metabolism*—The day to day variation in the basal oxygen consumption of a human was noted over a period of a month, all influence of change in environment and previous exercise being eliminated by making the determinations before the subject left his bed after a night's sleep. Each series of measurements by the helmet-spirometer type of apparatus was followed by a series with the helmet-rotamesser type. E. L. Fox had charge of these measurements.

*Effect of muscular exercise upon the metabolism of ethyl alcohol*—The effect of muscular exercise on the metabolism of ethyl alcohol has been studied extensively with a human subject. The respiratory exchange was measured during rest and during and after muscular work on a bicycle ergometer, by means of the helmet open-circuit respiration apparatus and gas analysis. The observations comprised control experiments with no dose and experiments in which the subject drank an aqueous solution containing 30 or 50 c.c. of ethyl alcohol. Determinations were made of the alcohol content of the urine, the blood and the ventilating air current.

*Metabolism during muscular work and the ingestion of sugars*—With the same apparatus employed in the alcohol study cited above the effect upon metabolism of muscular work and the ingestion of 70.5 grams of cane sugar or 50 grams of galactose was studied with a human subject. The experiments in this and the alcohol investigation were conducted by Dr. T. M. Carpenter, assisted by R. C. Lee, G. Lee, and Miss M. Burdett.

*Racial metabolism*—The various cooperative investigations that are being continued in the Nutrition Laboratory's extensive program of research on racial metabolism have already been cited on page 174.

#### EDITORIAL WORK

A large part of the fall and winter was spent in correcting the proofs of the monograph on "The Physiology of Large Reptiles." Mrs. Cornelia Golay Benedict kindly volunteered her services to prepare an exhaustive subject index, which meets fully the reader's needs in consulting the book on any particular topic.

A considerable number of manuscripts have been prepared during the year. The editorial program was almost exclusively in the hands of Miss Elsie A. Wilson, the Editor of the Nutrition Laboratory. Manuscripts that have been completed and accepted for publication are:

Effect of muscular activity on the metabolism of alcohol. (T. M. Carpenter. *Journal of Nutrition*, January 1933.)

Effect of combination of hexoses on the human respiratory exchange. (T. M. Carpenter and R. C. Lee. For the Proceedings XIVth International Physiological Congress, Rome, August 29 to September 3, 1932. An abstract of a paper to be presented before the Congress.)

Metabolism of normal and hairless mice at different environmental temperatures. (F. G. Benedict and E. L. Fox. *Pflüger's Arch. f. d. ges. Physiol.*)

Basal metabolism of small birds—canaries, sparrows and parakeets. (F. G. Benedict and E. L. Fox. *Pflüger's Arch. f. d. ges. Physiol.*)

Heat production of unusually large rats during prolonged fasting. (F. G. Benedict, K. Horst and L. B. Mendel. *Journal of Nutrition*.)

Physiology of normal and Frizzle fowl with special reference to the basal metabolism. (F. G. Benedict, W. Landauer and E. L. Fox. Storrs Agricultural Experiment Station Bulletin.)

In addition, the following manuscripts have been completely edited:

Problems in estimating the surface areas of animals of different species. (F. G. Benedict.)

Helmet respiration apparatus in its various forms. (F. G. Benedict.)

Apparatus for the analysis of gases from animal and human respiration chambers. (T. M. Carpenter.)

Effect of small quantities of galactose on the human respiratory exchange. (T. M. Carpenter and R. C. Lee.)

Comparison of the respiratory exchange of men and women as affected by the ingestion of galactose. (T. M. Carpenter and R. C. Lee.)

Comparison of the effects on the human respiratory exchange of hexoses ingested separately and together. (T. M. Carpenter and R. C. Lee.)

Other manuscripts in process of preparation but not yet completely edited are:

Basal metabolism of American-born Chinese girls. (F. G. Benedict and M. H. Meyer.)

Apparatus installed in the Laboratory for Animal Nutrition at Durham, New Hampshire, for the study of the metabolism of large domestic animals, with a description of the Ritzman apparatus for collecting separately the urine and feces of cows. (F. G. Benedict and V. Coropatchinsky.)

#### PUBLICATIONS

- (1) *The rationale of weight reduction.* Francis G. Benedict. Scientific Monthly, vol. 33, pages 264-266 (1931).

One of the Science Service Radio Talks presented over the Columbia Broadcasting System. Weight reduction should be a careful, intelligent curtailment of food intake, carried out slowly over a period of months and under the advice of a good physician.

- (2) *The energy and the protein content of edible food waste and mixed meals in sorority and fraternity houses.* Francis G. Benedict and A. Gertrude Farr. New Hampshire Agric. Expt. Sta., Bull. 261, November 1931. 35 pages.

The energy content of edible table waste, as distinguished from kitchen refuse, can be calculated with reasonable accuracy by multiplying the air-dry weight in grams by the factor 5, if visible fat is not present. If there is visible fat and it can be removed easily, its energy value should be calculated separately by multiplying its weight in grams by the factor 9, and the rest of the waste should then be considered to have an energy content of 5 calories per gram of air-dry matter.

- (3) *Body temperature and heat regulation of large snakes.* Francis G. Benedict and Edward L. Fox. Proc. Nat. Acad. Sci., vol. 17, pages 584-587 (1931).

The rectal and the mouth temperatures of the python are essentially the same. The temperature of the skin is somewhat lower than that of the rectum. The rectal temperature of the quiet, fasting snake is usually below the environmental temperature and increases or decreases with the changes in air temperature. During muscular activity and at the peak of active digestion the snake's temperature may actually be higher than that of its surroundings. Under conditions of post-digestive, muscular repose the



snake gives off no sensible heat by radiation, but loses all its heat through the vaporization of water.

- (4) *The incubating python: A temperature study.* Francis G. Benedict, Edward L. Fox and V. Coropatchinsky. Proc. Nat. Acad. Sci., vol. 18, pages 209-212 (1932).

The skin temperature of a female, incubating python was, on the average, 3° or 4° C. higher than the average temperature (30° C.) of the air surrounding her.

- (5) *The physiology of large reptiles, with special reference to the heat production of snakes, tortoises, lizards and alligators.* Francis G. Benedict. Carnegie Inst. Wash., Pub. No. 425, 1932. x + 539 pages. 106 illustrations.

After a period of 17 years of experimenting, first at the New York Zoological Park and subsequently at the Nutrition Laboratory, during which time nearly 1000 respiration experiments were made with 36 snakes, 8 lizards, 2 alligators and 11 tortoises, the results of these experiments were brought together in a monograph. Emphasis was especially laid upon the total metabolism, both basal, that is, in periods of repose and without digestion, and during digestion, with special reference to the effect of variations in environmental temperature. In addition, observations were made on respiration rate, mouth, rectal, and skin temperatures, water-vapor output, insensible perspiration, analyses of snake excreta, measurements of the body-surface area and the skin area of snakes, analyses of the water, ash, fat, and nitrogen content of the body of a snake, electrocardiograms of the tortoise, analyses of tortoise urine, and measurements of a snake skin, a tortoise skin, and a tortoise shell. These cold-blooded animals had a very low metabolism, a definite reaction to temperature changes with increased temperature resulting in increased metabolism, but even at the cell temperature of warm-blooded animals (37° C.) their metabolism was only about one-eighth that of the warm-blooded animal. It is concluded that the cold-blooded animal can not have a high metabolism because it has not a sufficient blood supply to the heat-producing tissues.

- (6) *Reptiles used in study of human physiology.* Elsie A. Wilson. Carnegie Inst. Wash., News Service Bulletin, School Edition, vol. 2, pages 193-197 (1932); republished in Scientific Monthly, vol. 34, pages 420-428 (1932).

A popular presentation of the results of the investigation reported in Carnegie Inst. Wash. Pub. No. 425 (see abstract No. 5).

- (7) *The surface-area constant in comparative physiology.* Francis G. Benedict. Yale Jour. Biol. and Med., vol. 4, pages 385-398 (1932).

A brief review is given of the different methods of measuring the surface area of animals and the constants published in the literature for use in estimating the surface area of different species of animals from the  $\frac{2}{3}$  power of the body weight. Details are recorded of determinations of body-surface constants for mice, sheep, snakes, and tortoises.

- (8) *Metabolism in Yucatan: A study of the Maya Indian.* Morris Steggerda and Francis G. Benedict. Amer. Jour. Physiol., vol. 100, pages 274-284 (1932).

A third expedition to Yucatan has confirmed the findings of two earlier expeditions, that the male Maya have a high basal metabolism and a low pulse rate. A group of 30 male Maya had a heat production averaging 8 per cent above the prediction standards for white men. The average pulse rate was 52 beats per minute, and rates as low as 34, 39, and 45 beats per minute were noted with several individuals.



- (9) *The metabolic rate in "hypnotic sleep."* J. C. Whitehorn, Helge Lundholm, Edward L. Fox, and Francis G. Benedict. *New Eng. Jour. Med.*, vol. 206, pages 777-781 (1932).

Simple "hypnotic sleep," with suggestions for relaxation and euphoria, may have an influence on metabolic rate determinations by eliminating or reducing the occasional high figures observed during the early training of subjects, but it does not reduce the rate below normal basal and apparently differs in this respect from normal sleep. The heart rate was slightly reduced by hypnosis.

- (10) *The basal heat production of elderly women.* Francis G. Benedict and Mary Henderson Meyer. *Proc. Amer. Philos. Soc.*, vol. 71, pages 143-165 (1932).

The basal metabolism of 23 women from 66 to 86 years of age (32 to 72 kg.) was measured with the helmet respiration apparatus. The metabolism was found to decrease with advancing age. All the women 78 years and over had a *total* heat production close to 1000 calories per 24 hours. This value may be accepted by the clinician without too great error as applicable to women 78 years of age and above. For elderly women under 78 years the relationship found between the measured heat production per kilogram of body weight and the weight could be used to predict with reasonable accuracy the probable basal metabolism, provided that one recognizes that at the heavier weights the metabolism per unit of weight will be lower with women of more advanced age than with those in the 70-year-old group. No correlation was noted between blood pressure and metabolism. The metabolism predicted by the Harris-Benedict formula agreed more closely with the measured metabolism than did the predictions by either the Aub and Du Bois or the Dreyer standard. But none of the existing standards may be considered to predict accurately the metabolism of any individual elderly woman.

- (11) *Some factors determining the insensible perspiration of man.* Francis G. Benedict and H. S. Halero Wardlaw. *Arch. Intern. Med.*, vol. 49, pages 1019-1031 (1932).

When measured under the usual conditions obtaining in basal metabolism experiments, the rate of insensible perspiration of an adult man became constant within 30 minutes after the assumption of the lying position. Changing from the lying to the sitting position caused an increase of 20 per cent in the rate of insensible perspiration under the special experimental conditions. Sleep during the daytime had no significant effect on the rate of insensible perspiration. Sleep at night lowered it markedly. About 15 per cent of the total loss by insensible perspiration was due to the loss from the surfaces of the hands and feet. Of the total skin loss, 30 per cent was derived from the surfaces of the hands and feet. The rate of loss from the hands and feet was approximately three times greater than that from the rest of the skin, per equal unit of skin area. Heating the feet increased the insensible loss considerably.

- (12) *Seasonal, endocrine and temperature factors which determine percentage metabolism change per degree of temperature change.* Oscar Riddle, Guinevere C. Smith and Francis G. Benedict. *Amer. Jour. Physiol.*, vol. 101, page 88 (1932).

The basal metabolism of various species and races of doves and pigeons markedly and similarly fluctuates with the seasons. The thyroids of these birds are larger and apparently more active in autumn and winter and smallest in summer; the gonads have a reverse relation to season. At the various seasons the metabolism is unequally affected by measurement at environmental temperatures higher or lower than 20° C. The "critical" temperature may vary with the seasonal and endocrine state of the animal.

- (13) *Metabolism during growth in a common pigeon.* Oscar Riddle, Theodora C. Nussmann and Francis G. Benedict. Amer. Jour. Physiol., vol. 101, pages 251-259 (1932).

The total metabolism at 30° C. of a race of common pigeons (tipplers) was measured at four early stages of rapid growth; basal values were obtained in one of the early stages, at three later periods of slower growth, at early and late adolescence, and after full sexual maturity. There is a low metabolism immediately after hatching, which is soon followed by the highest metabolism of the life cycle. From the 43-day and probably from the 28-day stage the metabolism progressively declines into adult life.

- (14) *The basal metabolism of the mourning dove and some of its hybrids.* Oscar Riddle, Guinevere C. Smith, and Francis G. Benedict. Amer. Jour. Physiol., vol. 101, pages 260-267 (1932).

Individuals of a feral, cold-avoiding, migratory species of doves, when reared in captivity, have been found to have a higher basal metabolism at 15°, 20° and 30° C. than that found in related, non-migratory, domesticated doves and pigeons. The metabolism of male mourning doves was higher at low temperatures and during all seasons than that of females.

- (15) *The racial element in human metabolism.* Francis G. Benedict. Amer. Jour. Phys. Anthropol., vol. 16, pages 463-473 (1932).

In three expeditions to Yucatan, male Maya were found to have a basal metabolism averaging 6.5 per cent higher than that of Caucasian men. South Indian women in Madras had a metabolism averaging 17.4 per cent below the standards for white women, and aboriginals (men and women) in Australia had a metabolism averaging 14 and 16 per cent below Caucasian standards. These differences in metabolism may perhaps be partly explained by differences in climate and food. Yet the climates and food habits (protein intake) of Yucatan and India are not so far unlike. American-born, pure-blooded Chinese girls in Boston had a metabolism 9 per cent lower than the standards for American white girls. In this instance climate and diet were more nearly comparable to those of the whites used for comparison. It is concluded that in addition to age, weight, height, and sex, the basal metabolism is also affected by race.

## DIVISION OF PLANT BIOLOGY<sup>1</sup>

H. A. SPOEHR, CHAIRMAN

Probably the most marked feature of research in biology since the beginning of the present century has been the phenomenal growth in efforts to apply the methods and concepts of physics and chemistry to biological problems. Stimulated by the method of thought, so successful in the physical sciences, of analysis in a search for simplicity, biology has largely devoted itself to the dictum that the activities of life are completely explicable in terms of mechanics, physics and chemistry. These efforts have now proceeded far enough to warrant the conclusion that the task of interpreting life phenomena on this basis will be vastly more difficult than was generally realized, and that the interpretation of coordination and integration of functions of a living organism and the reactions to its environment demand a store of information as yet largely non-existent in the disciplines of chemistry and physics. The physical environment itself is but imperfectly known and understood. Only a beginning has been made in gaining a more exact knowledge of the chemistry of the complex carbon compounds which play important rôles in living things. An examination of anatomical structure of plants in relation to function and to chemical composition of the component elements has hardly been begun. That with such a background advances should be slow in the interpretation of the activities of living things on the basis of physics and chemistry is by no means surprising. The task is vastly more laborious, time-consuming and exacting than investigations in the physical sciences. But it is only by the patient, persistent and unspectacular accumulation of facts that a sufficiently sound ground work can be built, on the basis of which the dictum can be tested.

For over three hundred years the philosophy of biology has witnessed the swing of the pendulum between extreme vitalism and extreme mechanism. Each return of the pendulum has found the subject enriched by some basic observations. But it is doubtful whether philosophical speculations can be very fruitful in such a fragmentary state of knowledge, nor is it surprising under these conditions that the philosophical thought of either extreme should produce some resonance in the biological thought of the time.

The Division of Plant Biology of the Carnegie Institution of Washington is composed of a number of sections constituting relatively small groups of workers devoting their attention to the study of some fundamental function of plants, of their origin and their modification. The rather diverse activities of the various sections represent somewhat different viewpoints on what are essentially closely allied problems. Opportunity is thus offered for a converging attack on a number of important biological problems with freedom for special emphasis of some aspects and for the manner of treating these as part of the larger problem.

The Division suffered a severe loss in the death of Harvey M. Hall on March 11, 1932. Dr. Hall had been associated with the Carnegie Insti-

<sup>1</sup> The Central Laboratory of this Division is located at Stanford University, California.



tution of Washington since 1918. During the first years his investigations were carried out at the University of California at Berkeley and later, with the organization of the Division of Plant Biology, facilities for his work were established at the Central Station of the Division at Stanford University. His broad interests in biology and his calm judgment were of great service to the newly formed Division and during 1930-31 he was its acting-chairman. In the year prior to his death, Dr. Hall and his collaborators made a thorough reexamination of the research program in experimental taxonomy and developed very carefully drawn plans for the prosecution of investigations in this field. A significant feature of the general method which Dr. Hall developed was the care and completeness with which records were kept of the experiments which, of necessity, covered long periods of time. This fact has aided very materially in the task of formulating a program for bringing to fruition the most important of his researches.

In September 1931, Dr. Jens Clausen, of Copenhagen, joined the staff of the section of experimental taxonomy as cytogeneticist. With the death of Dr. Hall, the most serious problem before this section was the framing of plans which would fully assure the security of the valuable experimental material which Dr. Hall had assembled, and which would carry to a conclusion the most important features of the program in experimental evolution. These objectives have been clearly defined and some noteworthy results have already been obtained through Dr. Clausen's application of cytogenetic methods to these problems. Especially significant results have been secured in the *Madinæ*, a group which Dr. Hall had been studying for twenty-five years. The supplemental information obtained through this newer viewpoint will give added importance to an extremely thorough investigation.

Although no definite conclusions have as yet been reached regarding the function of the red leaf-pigments, carotene and xanthophyll, in the mechanism of the photosynthetic process, the picture of the configuration of the molecules of these substances is becoming clearer, and more exact information has been gained of their properties. These substances have taken on greatly increased significance with the discovery that chemically and biologically they are closely related to vitamin A and to some of the important hormones of the animal body. So far as is known, the plant is the only source of these substances. An understanding of the changes which these highly complex molecules undergo in order to form the accessory factors of such profound importance to the metabolism of the animal organism is to a very large measure dependent upon an intimate knowledge of the structure of their molecules. This is undoubtedly also true of their function in photosynthesis and respiration in the plant. For these reasons the investigations on the molecular configuration of these pigments have been pursued as vigorously as possible.

It is important to realize that the photosynthesis taking place in the great majority of plants occupying the surface of the earth is paralleled in the general reaction by a type of photosynthesis which occurs in organisms which thrive under entirely different conditions. The beautifully col-



ored purple bacteria grow in the absence of oxygen, produce no oxygen as a product of photosynthesis and utilize hydrogen sulphide or related sulphur compounds and radiant energy for their development. Points of comparison and analogy in problems of this nature are of great value in leading to an understanding of the deeper relationships which may exist. The investigation on the pigments of green leaves and those of Dr. van Niel, of the Hopkins Marine Biological Station, on the purple bacteria have led to a cooperative research on the pigments of these organisms which promises valuable results.

The investigations of Dr. D. T. MacDougal on the growth in trees have during the past few years been supplemented by studies of the pneumatic system and of other structural elements in trees. The results of these observations covering an uninterrupted period of more than a decade, together with results obtained from experimental studies on the function of elements in tree stems, are being assembled for publication.

For a number of years regular expeditions have been made from the Desert Laboratory into the sparsely inhabited desert region to the southwest of Tucson for the purpose of gathering climatic data of this region, especially in relation to vegetation studies. A more extended exploration was undertaken this year, by a party under the leadership of Dr. Forrest Shreve, into the lower valley of the Magdalen and San Miguel Rivers, the region lying northwest of Hermosillo and that between Hermosillo and Guaymas. The purpose of the trip was a study of the composition of the desert flora and of the habitat requirements of the dominant plants, particularly in regard to physiographic and soil conditions. The region is one which is still only imperfectly known and over which a movement of plant stocks probably occurred from the south. A knowledge of the floristic and ecological plant geography of northern Sonora, southern California, southern Arizona, and Lower California is of great importance for an understanding of the history and development of the vegetation of the arid regions of North America. This region, still little disturbed by the influences of man, offers a unique opportunity for the reconstruction of the steps in the development of a great biological unit, for a study of the phylogenetic origin of its members and of the environmental influences which have shaped the development of the organisms.

During January and February of 1932, Dr. R. W. Chaney, accompanied by Dr. Erling Dorf of Princeton University, visited the lowland tropical forests of the British West Indies, British Guiana, Venezuela, Panama and Guatemala and the temperate rain forests on the middle slopes of the mountains of Venezuela, Costa Rica and Guatemala for the purpose of comparing the living forests of the neo-tropical region with the Eocene floras of western America and especially with the Goshen flora of western Oregon. The use of airplanes aided considerably in reconnaissance surveys in this difficult terrain, and these surveys were followed by detailed studies at suitable places indicated from the air. Many modern equivalents of the older Tertiary species of western America were observed, making possible the interpretation of certain of the fossil floras in terms of the surviving elements in the neo-tropical regions visited.

## PHOTOSYNTHESIS

## THE LEAF PIGMENTS

One of the primary objectives in the investigation of photosynthesis, conducted in this division during the past years, has been an understanding of the mechanism of the chemical reactions comprising the process in the living cell. In the main, two different, though complementary, avenues of approach have been pursued toward this end. The one, comprising a study of the energy relationships through thermal effects and based upon thermodynamical considerations, and the other, which embraces a study of the more strictly chemical or molecular changes involved, have revealed the necessity of more precise knowledge of the nature of the photosynthetic apparatus, that is, of the physical-chemical system of the photosynthetic cell. Our knowledge of the chemistry of chlorophyll and its related compounds has been decidedly extended within recent years, but regarding other important features of the photosynthetic apparatus little is known. For this reason during the past few years special attention has been focused on the yellow-orange pigments which are in the chloroplasts and are also wide-spread in the tissues of almost all living organisms. In the photosynthetically active cells, the interest centers primarily on the carotenes and xanthophyll. As to the possible function of these in photosynthesis there have for a long time been two schools: the one ascribes a purely chemical rôle to them, the other places chief emphasis on the optical properties of these pigments. It has become clearly apparent that discovery of the true function of these important elements of the chloroplast is in a large measure dependent upon knowledge of their chemical constitution and physical and chemical properties. Although composed of only two elements, carbon and hydrogen—but in the case of xanthophyll, also oxygen—these pigments are extremely complex molecules so that the determination of their chemical structure has been an unusually difficult and time-consuming task. The complexity of the problem has, moreover, been increased by the discovery that there are several distinct forms of carotene, though differing from each other only very slightly in regard to most of the chemical and physical properties. This has imposed many difficult problems and the devising of delicate techniques for the separation of the component pigments.

## HYDROGENATION OF CAROTENES

The carotene molecule exhibits an extraordinary degree of unsaturation. This is indicative of a large number of double carbon to carbon valence bonds, an arrangement of the molecule which is also responsible for its color. The exact determination of the number of such double bonds within the molecule is of great importance for the purpose of gaining an insight into the structure of such a complex molecule. The number of double bonds in an open chain of carbon atoms can best be established by determining the number of hydrogen atoms which are taken up by the molecule with the aid of a platinum catalyst. Dr. James H. C. Smith has continued his investigations of this aspect of the problem. He has devised a micro method of hydrogenation which by the use of only very small amounts of material, about 2 mg., gives results accurate to approximately 2 per cent.

In view of the fact that it has been found that carrot roots contain at least two different carotenes and that on purely theoretical grounds a large number of different isomeric carotenes are possible, it was important to determine whether the leaves of different species of plants all contained the same carotene or whether the molecular structure of the carotene varied with the species. Carotene was extracted from the leaves of the following plants: black fig (*Ficus carica* L., var. *hortensis*), chard (*Beta vulgaris* L., var. *cicala* L.), alfalfa (*Medicago sativa* L.), cauliflower (*Brassica oleracea* L., var. *botrytis* L.), spinach (*Spinacia oleracea* L.), sunflower (*Helianthus annuus* L.), and sugar-beet (*Beta vulgaris* L., var. *rapa* Dumort.). The yields from these different sources varied considerably, from 0.002 to 0.01 per cent of the dry plant material, so that many hundreds of kilograms of fresh plant material had to be worked through in order to obtain sufficient pure carotene for experimentation. This laborious task was carried out by Dr. H. M. Leicester, who has made a number of improvements in the technique of the process of extraction and purification of these pigments.

It was found that all of the leaf carotenes examined possess the same degree of unsaturation. They have ten double bonds in the molecule. This means that in respect to this fundamental property they are the same. The determination of the degree of unsaturation constitutes an essential basis for further experimental work and reasoning on the chemical structure of the carotene molecule.

It is frequently very helpful in problems of this nature to obtain evidence from allied fields for purposes of comparison. For this reason some work has been done with lycopin, the pigment of the tomato fruit. This pigment is, in many respects, similar to carotene; in fact, the number of carbon and hydrogen atoms in the two compounds are the same; the differences arise in the arrangement of the atoms within the molecule. By the same method of hydrogenation, lycopin, in conformity with previous findings, was found to contain thirteen double bonds. Also, dihydrocarotene which was prepared by the addition of two atoms of hydrogen to carotene was by this method found to contain nine remaining double bonds.

#### OPTICAL ROTATION OF CAROTENES

In order to determine by the use of another method whether carotenes from different plant materials are identical, Dr. Smith has made a careful study of the optical rotatory power of carotenes obtained from carrot roots and from the leaves of several different species of plants. In searching for differences in molecules that are so complex and so similar, optical methods probably offer the best means of attack. Moreover, the determination of the rotation of the plane of polarization of light by an organic compound is of much help in establishing the structure of the compound. A number of serious difficulties developed in the course of the investigation which necessitated the construction of special apparatus. The solutions are deep red and consequently absorb the wave-lengths of light which are usually used in polarimetric measurements, such as the yellow sodium and the green mercury lines. A source of intense monochromatic red light was found to be essential, and best results were obtained by the use of a hot cathode helium arc quartz lamp as recently developed by Dr. Rothen of the



Rockefeller Institute for Medical Research. By the use of Zeiss red (B) filter, approximately monochromatic red light of high intensity is obtained. Because the available polarimetric instruments, even with this source of light, did not allow enough light to pass to make accurate visual readings, a photographic instrument was devised which permitted long exposures and accurate readings of the angle of rotation. On carefully re-checking the determinations thus made, it was found that a shift in the zero point occurred when a red absorbing solution was put in the path of light. Consequently the readings are in error by an amount depending on the absorption of the solution. This will probably be from  $0.02$  to  $0.04^\circ$ . Although all of these determinations are soon to be re-checked by the use of a Winkel-Zeiss polarimeter, the important conclusion seems justified that none of the carotenes obtained from these leaf sources exhibit optical activity. Carrot carotene and dihydrocarotene showed values of dextro rotation which were entirely beyond the experimental error and, indeed, in the opposite sense of those inherent in the method employed. Dihydrocarotene thus showed a specific rotation of  $[\alpha]_{\frac{18}{6678}} +12.7$ . The rotation of carrot carotene varies according to the method of preparation, a value as high as  $[\alpha]_{\frac{18}{6678}} +113^\circ$  has been obtained without special treatment.

#### ABSORPTION SPECTRA OF CAROTENES

In conjunction with investigations of the absorption spectra of leaf pigments which Dr. Smith and Mr. Milner have had in progress for several years, the carotenes obtained from the different plant sources have been subjected to a comparative study. Frequently small differences in the constitution of organic compounds are revealed through differences in their absorption spectra. The absorption curves of carotenes from seven different sources have been studied in the region between  $5300$ - $2500$  Å. However, no significant differences were observed; in the visible region,  $5300$ - $4000$  Å., the absorption spectra of the leaf carotenes are the same within the experimental error. In comparison with these, the wave-length of maximum absorption for carotene from carrots is shifted approximately  $25$  Å. toward the violet. In the ultra-violet region the absorption spectra of all carotenes is the same. The results thus far obtained indicate a substantiation of the opinion that but two forms of carotene have been found in nature.

Dr. Smith has also obtained some confirmatory evidence concerning the identity of the leaf carotenes from solubility data. The solubilities of the carotenes from different sources and of mixtures of these were determined in hexane at  $25^\circ$ . The data indicate that carotene from carrot-roots is a mixture of two forms, while the carotenes from leaf sources are identical.

#### OZONIZATION OF CAROTENES

The current ideas concerning the structure of a carotene molecule are that it is similar in form to a dumbbell. A long straight chain of carbon atoms connects two rings, each containing 10 carbon and 16 hydrogen atoms. Dr. Strain has been engaged in the investigation of the arrangement of the carbon and hydrogen atoms within these rings. Through the action of



ozone under very carefully controlled conditions, the carotene molecule is broken into a number of fragments. From a study of the nature of these fragments the structure of the original carotene can in a measure be reconstructed, or at least some indications can be obtained relating thereto. One of the most difficult problems was the development of suitable methods for the identification and quantitative determination of the products resulting from the ozonization, for the reasoning by such a procedure must in a large measure be based upon quantitative considerations. Of special significance in these investigations has been the result that carotene on ozonization yields geronic acid, a compound of the formula,  $\text{CH}_3\text{C}=\text{O}.\text{CH}_2.\text{CH}_2.\text{CH}_2.\text{C}(\text{CH}_3)_2.\text{COOH}$ , and in quantities which would indicate that the original carotene molecule contains one group capable of yielding this compound. The same results were obtained with carotene from different plant sources as well as with dihydrocarotene. The quantitative determination of geronic acid was made possible through the development of a method which is based upon the formation of an insoluble compound of geronic acid with 2,4-dinitrophenylhydrazine. From these results it may be concluded that the geronic acid may arise from any of the following five structural units in the carotene molecule:

- I.  $\text{CH}_3 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \text{CH}_2 . \text{CH}_2 . \text{CH}_2 . \text{C}(\text{CH}_3)_2 . \text{CH}:\text{C}$
- II.  $\text{C}:\text{CH} . \text{CH}_2 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \text{CH}_2 . \text{CH}_2 . \text{CH}_2 . \text{C}(\text{CH}_3)_2 . \text{CH}:\text{C}$
- III.  $\text{CH}_3 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \text{CH}_2 . \text{CH}_2 . \text{CH}_2 . \text{C}(\text{CH}_3)_2 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \text{CH}:\text{C}$
- IV.  $\text{C}=\text{CH} . \text{CH}_2 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \text{CH}_2 . \text{CH}_2 . \text{CH}_2 . \text{C}(\text{CH}_3)_2 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \text{CH}:\text{C}$
- V.  $\text{CH}_3 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \underset{\text{C}:\text{C}}{\text{C}} . \text{CH}_2 . \text{CH}_2 . \text{C}(\text{CH}_3)_2 . \underset{\begin{array}{c} \parallel \\ \text{C} \end{array}}{\text{C}} . \text{C}$

Of these, Structure III, as it occurs in  $\beta$ -cyclo-citral and  $\beta$ -ionone, seems the more probable source of the geronic acid obtained by the ozonization and oxidation of carotene. Such a postulation would explain the source of the odor of violets possessed by partially oxidized carotene. Considerably more work will be required to establish definitely which one of these structural units exists in the carotene molecule.

Dr. Strain has also subjected lycopin to a similar treatment with ozone. Among the products levulinic acid,  $\text{CH}_3 . \text{CO} . \text{CH}_2 . \text{CH}_2 . \text{COOH}$ , and levulinic aldehyde were isolated in the form of their 2,4-dinitrophenylhydrazine derivatives. From these results it may be concluded that the lycopin molecule contains the  $\text{CH}_3 . \text{C} . \text{CH}_2 . \text{CH}_2 . \text{CH}=\text{C}$  or other closely

related group.

In as complex and difficult a problem such as is presented by the chemistry of photosynthesis it is important to make use of every available avenue of approach which, though at the time it may not seem to lead directly to the immediate goal, may yet serve as a valuable guide. In the purple bacteria there occurs a type of photosynthesis, in many respects differing from that occurring in green plants, but from the study of which important points of comparison have already been gained. In these organisms the photochemical reduction of carbon dioxide is linked up with the disappearance from the medium of hydrogen sulphide or other sulphur or organic compounds. Inasmuch as these different photosynthetic processes are all characterized by the fact that the organisms produce one or more pigments capable of absorbing the radiant energy required for the photochemical carbon dioxide reduction, such a comparison involves, among other features, a comparative study of the chemical study of the different pigments. These organisms have for a number of years been the subject of intensive study by Dr. C. B. van Niel of the Hopkins Marine Biological Laboratory, and during the past year he spent three months in our laboratory in a cooperative investigation of the nature of these pigments.

In order to obtain a sufficient quantity of pigment, large amounts of bacteria are required, and because differences in color have been observed among different representatives of the group of purple bacteria it was considered necessary to work with pure cultures only. The organism selected was a pure culture of one of the *Athiorhodaceæ*, identical with or closely related to *Spirillum rubrum*. Of these Dr. van Niel cultured large quantities from which he extracted the pigments and resolved them, so far as this was possible, with the methods available. In view of their extreme ease of oxidation, the operations must be carried out in vacuum or in an atmosphere of nitrogen. The amounts of pigments obtained are naturally very small; a total yield of only 26 mg. was obtained, so that micro methods had to be used throughout. A crystalline pigment was obtained which yielded beautiful purple solutions in carbon bisulphide. This pigment was subjected to examination by Dr. Smith and Mr. Milner by means of the apparatus and methods which have been developed for the investigation of leaf pigments.

Analysis showed the pigment obtained from the purple bacteria to be free from sulphur and nitrogen. Molecular weight and hydrogenation determinations as well as combustion analyses and the absorption spectrum in the visible portion of the spectrum were made. The pigment is so sensitive to ultra-violet light, that no spectrograms could be made in this region. The indications were that the pigment obtained still represented a mixture and this was substantiated by the results of an absorption chromatogram which showed that in all probability there were present three pigments—one brown, one purple and one red. These, however, are not all hydrocarbons; indications are that one of them, as in the case of xanthophyll from green leaves, contains oxygen. It may be pointed out that the apparent presence of a brown pigment in these purple bacteria is of decided interest since this may lead to establishing a relationship between purple bacteria and the "Phæobacteria."

## ANALYSIS OF THE PHOTOSYNTHETIC REACTIONS

The fundamental significance of the process of photosynthesis lies in the fact that through it the radiant energy of the sun is converted into the chemical energy stored in the carbon compounds which are the products of photosynthesis. In the large, the energy relations of the process are known with a fair degree of accuracy, but as an aid to the discovery of the chemical mechanism involved and for an analysis of the total process into the individual steps of the chain, much more refined measurements are necessary. The physical apparatus required for such an investigation is of necessity complicated and demands for its construction the designing, manufacture and testing of a variety of parts. Progress in this work has been slow, and owing to concentration of effort on other phases of the program only minor developments have been made in this portion of the project. In view of the fact that photosynthesis is most accurately measured through the interchange of carbon dioxide and oxygen, exact methods for estimating these gases comprise one of the most important features for experimentation. An extended series of experiments has been made to develop methods of a high order of accuracy for the determination of oxygen and carbon dioxide dissolved in water and for meeting some of special requirements set by the nature of the experimental conditions. The results of these tests are now being incorporated in the construction of apparatus designed for this purpose.

Although all green plants exhibit the power of photosynthesis, very few of them offer material suitable for precise experimentation. A variety of factors associated with structural peculiarities, the behavior of the stomata and nutritional requirements introduce variable factors which are beyond the control of the experimenter. During the past few years, an extensive search has been made for suitable plant material which is free from these difficulties. For the purpose in question, aquatic plants offer many advantages and a variety of these have been collected and their requirements for culture tested in aquaria at the Central Station of the Division. The most promising of these is *Cryptocoryne griffithi*, a broad-leaved submerged Aroid from Malacca, which in preliminary test has proved very promising.

## INVESTIGATIONS ON CAMBIUM AND ITS DERIVATIVE TISSUES

By I. W. BAILEY

## CYTOLOGICAL AND HISTOLOGICAL ASPECTS

Methods have been developed for studying the cambium and its differentiating derivatives, both in the living and fixed condition. These techniques are being applied at present in detailed investigations of plasmodesma, of cell membranes and of the cytological changes that occur during the differentiation of sieve tubes and vascular elements of gymnosperms and dicotyledons.

There appears to be no reliable evidence for assuming that true protoplasmic connections occur in the cambium or its derivatives, with the possible exception of sieve tubes. Nor is there evidence to indicate that protoplasmic streaming occurs in the mature sieve tubes of gymnosperms.



## PHYSIOLOGICAL AND BIOCHEMICAL ASPECTS

Detailed and reliable information concerning the cytology of the living cambium and of its differentiating and fully differentiated derivatives is essential for the solution of various physiological problems, i.e. such as are concerned with growth and differentiation of the xylem and phloem, storage and translocation of elaborated substances, movement of liquids and gases, etc. Progress is rendered difficult, however, by the lack of accurate microchemical methods. The attempt is being made, in cooperation with Professor Anderson of the University of Arizona, to develop methods for locating and studying the polyuronides and other complex polysaccharides *in situ*.

Investigations extending over a period of years demonstrate that growth in the cambium and its derivative tissues is largely of the so-called "sliding" rather than of the "symplastic" type.

## PALEOBOTANICAL ASPECTS

Much confusion exists at present, as in the past, in the identification of fossil woods. Investigations extending over a period of years indicate that this is due, in part, to the fact that evolutionary specialization in the xylem commonly does not closely parallel that in the flower or leaf and, in part, to the fact that comparatively little is known concerning the limits of variability of anatomical characters in living representatives of the gymnosperms and angiosperms. During the last year, materials were assembled for an intensive study of *Sequoia*, *Cedrus*, *Keteleeria* and other Coniferae. Specimens were secured from different parts of the tree and from trees grown under widely varying environmental conditions. Most of the anatomical characters that have been used for diagnostic purposes were found to vary within relatively wide limits. *Protopiceoxylon*, *Protocedroxylon*, *Planoxylon*, *Pinoxylon* and other supposedly extinct "transitional" Mesozoic genera fall within range of structural variability of living representatives of *Cedrus*, *Keteleeria* and of other Pinaceae. Certain of the putative Sequoias from the auriferous gravels of California are in reality *Cedrus*.

It is evident that future progress in those fields of paleobotany which are concerned with fossil woods is dependent upon the assembling of large collections of authentic specimens of living gymnosperms and angiosperms, not only from different genera, species and geographical races, but also from different parts of the tree and from trees grown under different environmental conditions.

Preliminary investigations of a wide range of dicotyledons from various tropical and temperate regions indicate that there is in many cases a high correlation between the structure of the xylem and the general environment in which trees grow. Thus, the wood of trees should ultimately provide extremely useful indexes for the study of climatic conditions during the Tertiary and Cretaceous periods.

## GROWTH IN TREES

## THE PNEUMATIC SYSTEM OF TREES, BY D. T. MACDOUGAL

Woody cells of tree trunks not filled with sap are occupied by atmospheric gases. The gas-filled elements constitute a meshwork in which changes in pressure are very readily communicated up and down the tree.

The pressure in the pneumatic system in a number of trees was found to be not more than 10 to 20 mm. of mercury above or below the barometric



pressure. When differences in pressure exceed the limits noted, actual streaming of gases into or out of the trunk ensues. It is remarkable that with such ready communication the gases drawn from tree trunks are in proportions widely different from that in which they appear in the air. The analyses of several hundred samples of gases extracted from *Pinus*, *Salix*, *Quercus*, *Juglans*, *Sequoia*, *Parkinsonia*, *Populus* and *Carnegiea* in a seven-year period beginning in 1925 show that carbon dioxide which occurs as 0.3 to 0.4 parts in a thousand in the air generally constitutes 10 to 260 parts of the gases in trunks. The carbon dioxide accumulating in the gas meshwork of trees may become dissolved in sap and be carried to the leaves where it would be available in the photosynthetic processes.

Oxygen which forms about 206 parts in 1000 of free air is most often found as making up 10 to 200 parts of tree gases. Some samples free of oxygen have been extracted. In a few cases oxygen occurred as 300 parts in a thousand of tree gases in the tree cactus and an Arizona poplar.

Nitrogen which constitutes about 780 parts in 1000 of common air varies from 770 to 830 parts in the gases of trees.

Terpenes have been recognized as one of the volatile substances suspended in the accumulated gases.

Carbon monoxide found by Langdon and Gailey as normally present in the bladders of Kelp (*Nereocystis*) has not yet appeared in analyses of tree gases.

Marsh-gas or any other inflammable gas has not yet been found in normal trees, although many reliable records of such substances as a result of internal decaying tracts are available.

#### AIR-PASSAGES IN THE CAMBIUM LAYER OF TREES, by D. T. MACDOUGAL

The gases in a stem which are in the intercellular spaces of the cortex communicate freely with the surrounding air through lenticels and stomata. Oxygen, carbon dioxide and nitrogen are generally present in this tract in proportions and at a pressure not widely different from atmospheric.

The gases in the woody cylinder inside the cambium show widely varying proportions, as noted in a separate paragraph. No passages by which gas might pass through the cambium layer by effusion or streaming have yet been demonstrated by the microscope. The fact that pressures of gases in the woody cylinder do not depart widely from barometric supports the inference that such passages do exist.

Recently obtained experimental results require the presence of such passages for their explanation. Several dozens of sections of stems of an oak (*Quercus agrifolia*) were sealed to sections of glass tubing filled with mercury. The tissues external to the cortex were cut away at the ends in making the connection, so that the weight of the column of mercury exerted suction on the wood inside the cambium only. Sections 10 to 20 mm. in diameter and 10 to 20 cm. long were used. Preparations of this kind were placed in a vertical position and the effects of suction from columns of mercury from 7 to 100 mm. were measured. The sections included an amount of air in the wood equivalent to about 5 to 6 per cent of their total volume. Extraction by suction was continued for several days and a total amount of air equivalent to 10, 20 or even 50 times the original content was obtained. As the free ends of the sections were securely sealed, actual infiltration or streaming of gases through the cambium as well as the cortex was denoted.

The tests with one section, in which suction varied from 80 to 100 mm. of mercury at room temperatures between 12° and 24° C., caused air to pass into the stem for the first few days at a rate of 0.008 c.c. per square centimeter of surface. Two weeks later the rate fell to 0.005 to 0.007 c.c. Tests of another section gave a rate of 0.010 to 0.017 c.c. per square centimeter per hour at the same time under the same conditions. Tests of other sections in a dark room at a constant temperature of 15° C. showed similar rates. The rate was but little affected by temperature. When the suction was decreased to 35 to 50 mm. of mercury, however, the rate of hourly infiltration per square centimeter fell to 0.003 to 0.004 c.c. hourly. The stems of this oak tree are rarely subject to differences of air pressure of this amount, and the usual rate of streaming may be conjectured to be near 0.001 c.c. per square centimeter per hour.

Sections of oak stems prepared as in the foregoing tests have been seen to hold up a column of mercury from 8 to 11 mm. in height for a month varying with the temperature and the barometer. This may be taken to be below the pressure necessary to cause a flow of air through the passages in the cambium layer. The air in a tree is thus seen to be enclosed in a cylinder of living cells, the cambium, which does not "leak" under this minimum pressure but does so at higher pressures.

#### GROWTH OF THE TREE-CACTUS (*CARNEGIEA GIGANTEA*), BY D. T. MACDOUGAL

The results of the dendrographic measurement of a tree-cactus for two years were published in 1924 (Carnegie Inst. Wash., Pub. No. 350, 1924, pp. 60-68). This was extended to complete a decade by a new dendrographic setting on a tree a meter in height and 30 years old in February 1924. A continuous record of changes in diameter until April 1932 was obtained. Pertinent accessory measurements of elongation and contraction of trunks and of roots for shorter periods were carried out.

The generative tracts of a woody tree of the ordinary type include vegetative points, terminating stems and branches, and the cylindrical sheet of cambium extending downward to the base of the trunk. The primary generative tract of a tree-cactus is in the form of a cone with rounded apex which extends down the trunk a length of less than 2 meters. Elongation of the trunk carries this cap upward. The dendrograph was affixed to the trunk in 1924 at a point about 30 cm. below the apex, in the middle of the growing zone. Before the close of the experiments, the generative tract had moved upward by 1929 so that the instrument was near its lower edge in 1931.

It was noted that with the localization of the growing region, capacity for division and growth was retained by thin-walled cells of the medulla and cortex for many years. Some of these cells are active for periods of 100 to 200 years. Elongation took place at the rate of 5 to 17 cm. (2 to 7 inches) annually, the record being 50 mm. in 1924; 60 mm. in 1925; 130 mm. in 1926; 96 mm. in 1927; 42 mm. in 1928; 70 mm. in 1929; 172 mm. in 1930; 75 mm. in 1931.

The volume of the generative tract increases but little after the plant reaches a height of 2 meters, but the green surface and consequent food producing capacity rises. The average area of the green surface of No. 33 was 4000 sq. cm. The fluted surface of the trunk results in a much greater absorption of radiant energy than would take place in a smooth cylinder. Accretion to the dry material of the trunk was at the rate of 0.375 gram annually for every square centimeter of green surface. Calcium and silica

are present in high proportion, so that the net amount of organic material formed is probably about 0.2 gram annually. Active growth takes place at temperatures of 20° to 40° C. of the generative cells.

SEASONAL ACTION OF THE REDWOOD (*SEQUOIA SEMPERVIRENS*),  
BY D. T. MACDOUGAL

Dendrographic measurements have been carried out on a suite of redwood trees in Rocky Creek Canyon leading directly to the sea at a place 15 miles south of Monterey since 1923. Since this forest is not far from the southern limit of the species, a reconnaissance was made to ascertain how near to the average performance was under observation. It was found that seasonal activity was approximately coincident throughout the range of the species. The thin filamentous roots elongate through the winter.

The formation of new leaves begins in March, and increase in the trunks takes place from April to October. Individual exceptions have been noted. Five, six or even seven annually formed suites of leaves are carried. The total surface of a single leaf is approximately 100 sq. mm. These leaves are flattish and are held at a right angle to the axis of optimal illumination. The energy trapped is much less than that of a leaf of the Monterey pine which is nearly cylindrical and has an average surface of 109 sq. mm.

COMPARISON OF DENDROGRAPHIC RECORDS MADE BY THREE SIMILAR  
INSTRUMENTS ON ONE TREE, BY FERDINAND W. HAASIS

Inasmuch as trees are sometimes found in nature with boles of oval or elliptical cross-section, it is obvious that differences in growth rate are to be expected in different diameters. For a short period of time, however, these should be slight, and records made by two similar dendrographs on one tree measuring diameters at right angles should afford a check on the dependability of dendrographic studies. For the purpose of making a comparison of this kind, such a pair of dendrographs was run on a Monterey pine tree, 25 cm. in diameter, for two weeks in January 1932.

At the same time records were obtained by a third instrument measuring a diameter parallel to that of one of the others. With this arrangement of dendrographs it was possible to compare the graphs made by similar instruments with different magnifications, and by instruments upon which the sheets were changed at different times of day.

These three instruments were 10 dm., 13 dm. and 17 dm., respectively, above the ground. Magnifications were as follows:

	Jan. 6-11	Jan. 11-18	Jan. 18-20
No. 20 (10 dm. above ground) . . . .	×11	×11	×11
No. 20-D (17 dm. above ground) . . .	×10	×20	× 9
No. 20-E (14 dm. above ground) . . .	×22	× 8	×10

The contact rods of No. 20 were at right angles to those of the other two. The recorder of No. 20 was on the north side of the tree, those of the other two on the west side. On January 18 sheets were changed as follows: No. 20-D, 7<sup>h</sup>30<sup>m</sup> a.m.; No. 20-E, 1<sup>h</sup>15<sup>m</sup> p.m.; No. 20, 3<sup>h</sup>20<sup>m</sup> p.m. At the earliest time, the diurnal contraction was about to begin, at the second time it was nearly complete, and at the third time, contraction had ceased and swelling was perhaps just commencing.



The dendrograms obtained in this series of observations show no essential difference between the No. 20 and the No. 20-D records during the first period, nor between the three for the third period. In other words, they give no indication of material differences in diametral fluctuations between nearly adjacent diameters lying at right angles to one another. The time at which the sheets are changed does not appear to have any influence on the character of the record.

When the diametral differences, either for the week or for a day are divided by the magnification factors, there is found to be no appreciable difference in result between the records obtained with the instrument magnifying 8 times and that magnifying 20 times.

It thus appears that, generally speaking, no significant errors are to be expected due to the particular diameter measured, to the time of changing sheets, or, within moderate limits, to the amount of magnification.

#### FURTHER RECORDS OF ESSENTIALLY CONTINUOUS GROWTH IN TREES, BY FERDINAND W. HAASIS

Essentially continuous growth for periods of many months has already been recorded by Doctor D. T. MacDougal for several trees of Monterey pine.<sup>1</sup> The past year's dendrographic records have afforded further evidence of this tendency in another Monterey pine and also in a Monterey cypress.

In the fall of 1931 a dendrograph was attached to a garden tree of Monterey cypress about 12 cm. in diameter. Irrigation places this tree beyond the influence of drought as far as soil moisture is concerned. Summing the diametral changes by fortnights, this tree has shown no pause in growth from early October up to the middle of June.

The pine tree referred to (No. 33) was also 12 cm. in diameter at the time dendrographic measurements were begun late in 1930. This tree stands on the grounds of the Coastal Laboratory at the foot of a fixed dune, where soil moisture is fairly abundant throughout the year. On the fortnightly basis this tree, too, showed no cessation of growth between September 1931 and June 1932. Indeed, growth was continuous for the entire year of 1931 in spite of the fact that pine trees in less favorable situations at the Coastal Laboratory showed marked shrinkage during the exceedingly dry summer and fall.

Fortnightly summaries of diametral increases in these two trees for the fall, winter and spring are given in the accompanying table.

These figures show the general trend of diametral growth. It is to be observed, however, that growth is not to be regarded as continuous throughout any two-week period. Expansion is daily checked or masked by shrinkage due to water deficit in clear weather, and sometimes a tree may have a lesser diameter on any given day than 24 hours previously. Even if the records of change in these trees were tabulated by weeks instead of by fortnights, the periods of continuous growth would naturally be shorter than shown in the table. For some weeks, indeed, there would be shown slight shrinkages. The fortnightly basis has been chosen as giving a reasonably clear picture of the progress of growth. At any rate,

<sup>1</sup> D. T. MacDougal and F. Shreve, *Growth in trees and massive organs of plants*, Carnegie Inst. Wash. Pub. No. 350, pp. 7, 8, 1924.

D. T. MacDougal, *Trees as recorders, in reports of Conferences on Cycles*, pp. 30, 31, 1929.

D. T. MacDougal, *Lengthened growth periods and continuous growth*, Proc. Amer. Philos. Soc., vol. 69, pp. 329-345, 1930.



the figures given indicate that a prolonged dormant period of several months' duration is not necessary for these trees during every period of cold weather or scanty rainfall.

*Diametral increases, in millimeters, of two coniferous trees in Monterey County, 1931-1932*

Fortnight ending	Monterey cypress No. 2	Monterey pine No. 33
1931		
Oct. 19....	0.45	0.32
Nov. 2....	.40	.18
16....	.20	.64
30....	.10	.27
Dec. 14....	.25	.05
28....	.25	.59
1932		
Jan. 11....	.05	.45
25....	.30	.73
Feb. 8....	.65	1.23
22....	.40	.91
Mar. 7....	1.10	1.86
21....	.75	1.18
Apr. 4....	1.50	1.23
18....	1.15	1.28
May 7....	1.10	1.32
16....	1.35	1.86
30....	1.30	1.50
June 13....	.15	1.09
27....	.50	1.19

PERIOD OF ENLARGEMENT FOLLOWING SEASONAL SHRINKAGE,  
BY FERDINAND W. HAASIS

Seasonal shrinkage of coniferous trees has been referred to in Year Book No. 30, and discussed in a paper published subsequently.<sup>1</sup> An analysis of the dendrographic records for the years 1931 and 1932 reveals a rather astonishing variation in diameter of some of the trees.

One Monterey pine tree began to shrink in the week ending March 30, 1931. This tree was 57 cm. in diameter and the dendrograph contacts were 13 dm. above the ground. Although shrinkage was not continuous during the next few months, being interrupted from time to time by diametral increases, yet the diameter of March 23 was not reattained; and by November 2 the diameter was 1.70 mm. less than at the beginning of the shrinkage. After November 9, the prevailing diametral change was an increase. The tree did not, however, regain the diameter of March 23 until the last week in February 1932. In other words, for a period of nearly 11 months the tree was smaller than it had been when seasonal shrinkage began in the spring of 1931.

A redwood, 48 cm. in diameter and growing about 19 km. from the pine tree just discussed, had a somewhat similar history. The dendrographic contacts on this tree are 17 dm. above the ground. Seasonal shrinkage began in the week ending September 7, 1931, and continued with some interruptions until the first of March 1932. The extreme minimal diameter for this period was 1.54 mm. less than at the beginning of the shrinkage.

<sup>1</sup> Ferdinand W. Haasis, *Seasonal shrinkage of Monterey pine and redwood trees*, Plant Physiology, 7, 285-295, 1932.

Diametral increase began again about the middle of March 1932, but it was nearly two months before the diameter of August 31 was again reached. It is thus seen that in this case the tree for 8 months was smaller in diameter than at the beginning of the period.

GROWTH AND DIURNAL FLUCTUATIONS IN A BIG-LEAF MAPLE AND A CALIFORNIA LAUREL, BY FERDINAND W. HAASIS

In the early fall of 1931 the dendrographic investigations were extended to two angiospermous species not previously studied in this manner. Both of these, big-leaf maple and California laurel, are found in the redwood stands and it was desired to compare their performance with that of the redwood trees as well as with one another. The maple is a deciduous tree. The laurel, on the other hand, has been reported by W. L. Jepson to hold its leaves for as long as 4 or 5 years. It is thus quite similar in this respect to the redwood, whose leaves, according to our observations, persist for about 4 to 7 years. The laurel is one of relatively few species of the broad-leaved trees of temperate regions which hold their leaves in this manner.

During the autumn, the seasonal shrinkage of the laurel ran closely parallel to that of a couple of redwood trees standing about 0.1 km. distant. In the case of one of these trees, growing on a south exposure, diametral increase for the season began in the middle of February. The laurel and the other redwood, both situated on slopes with northerly exposure, did not begin their seasonal increase until early in March. This difference in the date at which the spring increase began is almost certainly referable to the fact that on the south exposure temperatures favorable for growth were attained earlier in the season than on the north exposure.

The maple tree, also situated on a north slope, and about 0.5 km. from the two redwoods referred to as controls, showed little diametral variation, week by week, until the first of December, when a seasonal shrinkage started and continued until the diameter began to increase the first part of May. At this time the leaves had been apparently full size for about a month. In the preceding autumn, leaf fall had begun before the end of September and was complete in the latter half of October. Swelling of the buds started before the middle of March 1932.

The above-described performance of the maple is quite similar to that of another deciduous tree, an Arizona walnut, growing at Carmel. In this tree, while the leaves were unfolding early in February 1932, the diameter of the trunk decreased for about a month while the leaves increased in size. A nearby Monterey pine tree, with its complement of evergreen leaves, was growing steadily in diameter throughout this period.

During the leafless period, diurnal fluctuations in the maple, like those in the walnut, were almost absent, even on clear days, but became greater after the development of the leaves. The reduction in amplitude of diurnal fluctuations in the redwoods and the pine referred to as controls was less marked in the winter period than in the case of the deciduous trees. In the laurel the amplitude in both winter and spring was intermediate between that for redwood and maple; on the whole, more like that of the maple. It might perhaps be expected, in view of the similarity in foliage persistence, that the laurel's behavior in this respect would be more like that of the redwood. It is to be observed, however, that in the case of both maple and laurel, the dendrographic contacts are on the outside of the thin smooth bark, whereas on the redwoods the bark is pared down to a thickness of 1 or 2 mm.

GROWTH AND DIURNAL FLUCTUATIONS IN A DECIDUOUS GYMNOSPERM,  
BY FERDINAND W. HAASIS

By far the greatest number of dendrographic studies have had to do with trees of two evergreen gymnospermous species, Monterey pine and redwood. Those studies which have been made of deciduous angiosperms indicate a considerable difference between their growth program and that of the two conifers just mentioned. It seemed desirable therefore, to extend the studies to a deciduous gymnosperm.

Coniferous species having this characteristic are known in three genera, *Larix*, *Pseudolarix* and *Taxodium*. The bald cypress, *Taxodium distichum*, was chosen for this study because trees of this species are known to have reached a fair size in the open in Monterey County, not far from Carmel. A small tree of bald cypress, 1 meter high and 1 cm. in diameter, was accordingly planted in low ground at the Coastal Laboratory in the autumn of 1931. While this species is wholly deciduous in some localities, there were a few leaves of the preceding year's crop still clinging to the tree in the middle of February, at which time the buds were beginning to swell.

During periods of unusually high water in December 1931 and January 1932, stream-borne sand was deposited around this bald cypress tree to a depth of about 25 cm. At the time when a dendrograph was fitted about this tree, in the middle of February, the roots were below the water-level in the soil, and remained so for several weeks. In spite of this fact, however, diurnal fluctuations were found to occur, amounting to as much as 0.01 of the diameter.

For a period of a couple of months this tree did not show any definite increase. In fact there was a slight net diminution in diameter. During this time the leaves were developing and elongation of the stems was taking place. Toward the end of May, however, a diametral increase began and continued through June. The leaf complement was then about complete, and the leaves were nearly if not quite full grown. It is thus evident that the behavior of this deciduous gymnosperm is quite similar to that of deciduous angiosperms. In the bald cypress, as well as in broad-leaf maple and Arizona walnut, diametral increases must wait upon the development of a complete or nearly complete leaf equipment. In the evergreen trees like pine, redwood and California laurel, on the other hand, such enlargement can take place whenever both temperature and soil moisture conditions are favorable.

REVERSIBLE VARIATIONS IN DIAMETER OF A TREE-CACTUS,  
BY D. T. MACDOUGAL

The central, woody cylinder of the tree-cactus is surrounded by a cortex several centimeters in thickness. The variations in diameter of the trunk are a direct expression of the degree of turgidity or hydration of the living cells of the cortex.

The tree cactus shows the paradoxical condition of the lowest rate of water-loss in the hottest part of the day. This results from the gradual closure of the stomata in the early part of the forenoon. The opening of the stomata at night allows an increased rate of water-loss and a shrinkage of the cortex. This is connected directly with the increased acidity of the cells at night. The acids (chiefly malic) are broken down by light. The cortical cells, with an acidity thus lessened, display a greater swelling power or water-holding capacity.



A small tree-cactus has been seen to take up 53,400 c.c. of water in 110 hours during the summer rains, with a total increase of 42 mm. in diameter. Water constitutes 90 per cent of the weight of a tree-cactus. One-third of this may be lost without damage to the plant, except to retard growth. On the other hand, so much water may be taken up in the rainy season that ruptures of the epidermal system occur which cause the death of the plant within a year or two.

SHRINKAGE IN A WIND-DWARFED REDWOOD AND IN A DECAPITATED REDWOOD,  
BY FERDINAND W. HAASIS

On the seaward edge of the redwood stands which occupy small canyons on the Monterey County coast there occurs a strip of trees which have been much dwarfed by wind action, the outermost individuals being reduced to mere shrubs. Dendrographic records made of a tree about 17 cm. in diameter and 5.5 meters high standing in such a strip indicate that in five out of six seasons of observation it suffered a net loss in diameter at a height of 1 meter from the ground. For the six seasons the total shrinkage was 3.8 mm., or about 0.02 of the diameter. At the same time, another redwood, more favorably situated, about 0.5 km. distant and 45 cm. in diameter, showed yearly increases, with a total of 26.0 mm., or 0.06 of the diameter.

The records upon which these observations are based were begun in April, May or June of each year and continued until October or November. Although the control tree showed such a definitely different program of diametral change from that of the wind-dwarfed tree, yet it seemed desirable to check the performance of the latter throughout a season. The dendrograph was therefore reattached to the wind-dwarfed tree in the summer of 1931, and records have been continued throughout the winter. By the middle of June 1932, the net diametral change in the wind-dwarfed tree has been a decrease of 1.72 mm. For the same period, the control showed a net increase of 1.33 mm. The change in the wind-dwarfed tree from October 25, 1931, to May 19, 1932, was a decrease of 0.78 mm. For the control it was an increase of 0.87 mm. These are the average dates between which operation of the instruments was suspended in earlier years.

From these figures it appears that the observed shrinkage of this tree between May 1924 and November 1929, can truly be regarded as an actual net decrease in diameter at the height at which the study was made.

Another redwood tree about 0.5 km. from the wind-dwarfed tree and 0.1 km. from the latter's control was topped at a height of 2 meters in July 1924. Since that time, it, too, has shown progressive shrinkage, whereas a control 1 meter distant has been growing from year to year. The amounts of change are shown in the accompanying table.

In 1932 the decapitated tree is 12 cm. in diameter at the height of the instrument; the control is 23 cm.

Doctor I. W. Bailey kindly examined under the microscope a sample of wood taken in the summer of 1931 from the decapitated tree 7 dm. below the instrument. He found that no wood had been produced subsequent to a relatively thick ring presumably laid down in 1924.

At the same time that this shrinkage is taking place in the lower parts of these two trees—the wind-dwarfed individual and the topped one—new wood is being laid down in the crowns. New branchlets are produced year after year in the top of the wind-dwarfed tree. While many of these are subsequently killed back, the fact remains that growth takes place at the top of the tree while shrinkage is occurring near the base. There is even



some evidence that the upper part of the bole may increase in diameter while the lower part is decreasing. This would result in a reduction of taper. On the decapitated tree, branches originating just below the cut continue to elongate from year to year. In early June 1932 the current year's growth on these branches was about 15 to 25 cm. long. There are five of these branches within 15 cm. of the cut top.

*Diametral changes in a decapitated redwood and in a nearby control*

Period of observation	Decapitated tree (topped July 10, 1924)	Control
May 6-July 10, 1924.....	0.6mm.	1.6mm.
July 10-Oct. 20, 1924.....	0.1	-0.1
April 15-Oct. 19, 1925.....	-0.2	7.2
April 15-Nov. 1, 1926.....	-1.1	7.6
April 15-Oct. 10, 1927.....	-0.6	9.0
June 5-Oct. 29, 1928.....	-0.1	1.7
April 13-Dec. 23, 1929.....	1.0	6.9
April 22-Dec. 29, 1930.....	-0.4	3.1
Dec. 29, 1930-Dec. 28, 1931.....	-1.0	3.6
Dec. 28, 1931-June 13, 1932.....	-0.6	5.8
Net since decapitation date.....	-2.9	44.8

### EXPERIMENTAL TAXONOMY

BY JENS CLAUSEN, DAVID D. KECK AND WILLIAM M. HEUSI

The late Dr. H. M. Hall was chiefly responsible for the organization of this comprehensive program of investigation. In briefest summary, the objectives of the section have been: (1) To make contributions toward a rational and complete classification of the products of organic evolution, and (2) to further our understanding of the processes operative in the development of these products. Although Dr. Hall and his staff were attacking their problems from the angles of comparative morphology, ecology, transplant experiments, statistics, field and herbarium studies and by consultation with historic specimens and literature, it was also realized that the complete picture of evolutionary processes could only be obtained through the pooling of these data with those from related fields, especially cytology and genetics.

#### PROBLEMS AND OBJECTIVES

This may be called a joint study of the products of organic evolution as they occur under natural conditions. Such a study embraces the variation and distribution of these products; their aggregation into taxonomic and ecologic units; their genetic, cytologic and eventually their physiologic differences; their environmental responses and their various types of relationships. All this should lead to and form the proper background for a study in experimental evolution and phylogeny of certain groups of plants, particularly chosen for their suitability for such joint study. Wherever possible, the results thus obtained through analytical studies are being substantiated by synthetic methods.

There are two very significant points in this program: one is that the materials utilized and analyzed in the investigations have to be the direct

products of natural, organic evolution; the other, that each problem is subjected to joint attack by several different methods.

#### METHODS

*Field Study*—Observations are made upon the geographic distribution of the forms under investigation, their distribution under various climatic and edaphic conditions, their variation over large areas and within local colonies, and with reference to their stability, frequency, associates, habitat preferences and so on.

*Experimental Evidence as to the Nature of the Variation*—It is essential to know whether observed variations are hereditary or ephemeral modifications due to the environment. This is tested by (a) transplanting different variations from different localities to a uniform (standard) environment at one station; (b) transplanting parts of one individual to several environments, both climatic and edaphic.

*Comparative Morphology*—Studies are made upon garden plants as well as upon large suites of specimens from various herbaria.

*Cytological and Anatomical Investigations*—These cover the various taxonomic units of all ranks and from as many areas within the general range of distribution of the material as advisable or possible.

*Genetical Analysis*—The differences underlying the taxonomic (principally morphologic) differences are being analyzed genetically as far as this is feasible. This involves the study of crosses between races, subspecies and species or even genera. It also covers a very important study of different degrees of intersterility or incompatibility, because this information is suggestive of the way species become separated during their evolution.

*Synthesis of Groups*—With taxonomic, cytologic and genetic data at hand, it is often possible to form hypotheses as to how certain groups have evolved from others. The attempt is made to repeat Nature's course of evolution by laboratory manipulation. Success can be achieved probably in only a very few cases, mainly in the younger groups of plants where relatively few of the variations have been exterminated.

#### MATERIALS AND RESULTS

Four groups of plants from well-separated families constitute the principal materials under investigation.

#### MADINÆ

The main emphasis has been put on the investigation of this subtribe of the Compositæ. It was Dr. Hall's expectation that the experimental work in this group would be practically completed during the season of 1932. It was not known before his death that the group was adapted to much more intensive cyto-genetic investigations than he had visualized. This discovery, together with the loss of Dr. Hall to this project, has made it necessary to plan to continue these experiments considerably further.

The preparation of manuscript for the taxonomic account of the Madinæ has progressed considerably since the last report, as has the accumulation of experimental and field data on the group. Dr. D. A. Johansen has completed his cytological study of the Madinæ. His work this year has been in cooperation with that of Dr. Clausen, and the cytological aspects of the group have been studied intensively. All of the species and forms in the gardens this year and nearly all of those available last year have been sub-

jected to examination. This has given cytological information on the large majority of species in the subtribe, and from this preliminary report many interesting facts have come to light. All chromosome numbers from four to sixteen inclusive have been found. No polyploid series has been discovered, which is a rare situation and adds to the cytological interest in the Madinæ. Fragmentation of the somatic chromosomes has been found to occur frequently in more than one genus. An outstanding discovery is that in a few cases there are differences in chromosome numbers within a single species (in the present taxonomic sense). The gametic chromosome numbers for the various genera, as far as they have been determined, are:

*Achyrachæna*—8 :

*Lagophylla*—7

*Holozonia*—14

*Layia*—7, 8, 9

*Madia*—7, 8, 9, 15, 16

*Hemizonia* section *Euhemizonia*—8, 14

*Hartmannia*—4, 6, 8, 9, 10, 11, 12, 13, 14, (21)

*Calycadenia*—5, 6, 7

*Centromadia*—9, 12

*Fruticosi*—12

Technically the Madinæ are better adapted for genetic experiments than many other Compositæ, for emasculation is easy, demanding only removal of the disk-flowers.

Genera in the Madinæ seem to lie very close together. It is difficult in many cases to arrive at a decision as to whether the morphological differences justify generic separation. One gathers the impression that this is a very young subtribe with the evolutionary trends within it still active. The interesting transitional forms are still in existence in many cases. The classification and delimitation of genera, species and their subdivisions in the Madinæ demand experimental evidence from the fields of genetics, cytology, ecology and comparative morphology and because of its suitability and availability for joint attack from various viewpoints it presents an excellent problem in experimental evolution.

#### ZAUSCHNERIA

Transplant experiments upon this genus of the evening primrose family have been reported in Year Books Nos. 29 and 30. Cytologic investigations have since shown that, although there may be but one all-inclusive taxonomic species in the genus, there are at least two genetic species.

The narrowest-leaved types from southern California, *Z. microphylla*, are diploid— $2n = 30$ . This form is rather coastal and has not been found above 2000 feet altitude.

The slightest increase in leaf-width is connected with tetraploidy ( $2n =$  about 60). *Zauschneria latifolia*, *Z. californica* and part of the former *microphylla* are tetraploid. It is impossible, by their morphological characters, to distinguish with certainty between the narrowest-leaved tetraploids and some diploids.

Santa Catalina Island types are narrow leaved and some of them are tetraploid while others are apparently pentaploid. No diploid type has been discovered on this island, although it occurs on the opposite mainland coast.



A colony of rather broad-leaved plants from Trinity River, Humboldt County, northern California, whose morphological characters marked it as somewhat different from all other *Zauschnerias*, was found to be composed of diploids. It is geographically well separated from the southern diploid, *microphylla*, by a distance of about 500 miles.

Mr. Heusi has made a few preliminary crosses that are of interest. Diploid *microphylla*, crossed with tetraploid *latifolia*, produced a sterile hybrid. The tetraploid *latifolia* (broadest-leaved type), crossed with tetraploid *californica* (intermediate leaf-width type), produced a fertile hybrid. The  $F_2$  is showing a striking segregation this year covering types from *latifolia* to *californica*. A number of diallel crosses between selected types are being made this year in the hope that they will throw light upon (a) the limits of interfertility and intersterility of the forms; (b) the possibility of synthesizing the gamut of variations that are observed to occur in nature; and (c) the inheritance of the most significant morphological character from the viewpoint of classification in this case, namely, leaf-width.

The transplant studies in *Zauschneria* have been extended in order to test thoroughly the rôle played by environment in the morphological situation. Some anatomical differences that occurred on portions of the same individual subjected to different environments have been investigated.

#### PENSTEMON

This appears to be strictly a polyploid genus. The chromosome numbers of 25 collections have been determined by a preliminary study. Together with counts previously reported by other investigators the situation is as follows:  $n = 8$  in 25 species;  $n = 16$  in 2 species;  $n = 24$  in 1 species;  $n = 32$  in 2 species;  $n = 48$  in 1 species.

Thus the majority of species are diploid, but polyploidy occurs in all sections examined of the genus. Dr. Keck, in his recent publication on the section *Saccanthera*, proposed the theory that *Penstemon neotericus* was of hybrid origin and suggested that the parents were *P. lætus* and *P. azureus*. Cytological verification of this theory is at hand, for the haploid number of *lætus* is 8, of *azureus* is 24 and of *neotericus* is 32 (?), the last being the sum of the numbers of the supposed parental species. This evidence carries more weight when it is remembered that polyploids are rare in *Penstemon* and that the new octoploid species occupies a Sierran area connecting the areas of its two diploid and hexaploid supposed parents.

Additional manuscript of a taxonomic monograph of the genus was compiled during the past year, but this work is held in abeyance at present while the Madinæ problem is being completed. Of genetic interest is the attempt to synthesize *Penstemon neotericus* from a cross between the supposed parental species *lætus* and *azureus*.

#### POTENTILLA

While the studies in individual modification in this genus, discussed in previous annual reports, have been continued, a cyto-genetic survey of the accumulated material has also been made. The latter investigations indicate that the astonishingly variable *Potentilla rupestris* group (in the broadest sense, including *P. glandulosa*) constitutes one intercrossing and interfertile community, subdivided into numerous ecotypes and microspecies adapted to widely varied conditions.

Seven different types of *P. rupestris*, from different localities, had a somatic chromosome number of fourteen. This low chromosome number does not suggest apomixis in this species as reported for some European



species of *Potentilla*. Crosses between the two most different types succeeded also and yielded many seeds.

#### MISCELLANEOUS MATERIALS

Material of the genus *Viola* was brought to the Institution by Dr. Clausen. The objective of the *Viola*-work is to continue and complete researches begun fourteen years ago. At the present stage the studies are mainly along the line of experimental evolution. At this time the work centers upon an attempted synthesis of *Viola arvensis* from the cross *V. kitaibeliana nana*  $\times$  *V. tricolor*.

A number of new species which arose by artificial hybridization are being followed generation after generation. It is the objective to observe whether these are indefinitely stable, cytologically as well as morphologically.

Finally, the pure strains which were utilized in previous investigations and hence became valuable test strains are being renewed. Some taxonomically interesting crosses must be postponed for the present.

Studies upon the miscellaneous groups of transplants are also being continued and the results assembled as part of the general program.

#### DESERT INVESTIGATIONS

##### UNDER THE DIRECTION OF FORREST SHREVE

There is every evidence that the plants and animals of desert regions are descended from forms which inhabited the moist parts of the earth. Many of the higher animals have entered the desert by the adoption of new habits, without material change in structure, and many plants common to moist and arid regions are able to enter the desert at favorable seasons but not to withstand its most rigorous conditions. Certain insects and reptiles and the majority of plants, however, have colonized the desert through the acquisition of structural and functional features unlike those of their ancestral forms.

The four great desert areas of the world bear evidence that the development of the life which is characteristic of them has proceeded along independent lines. Different families and different genera have contributed to their biota, and the life in each of them shows its closest relationship to that of adjacent regions of greater moisture rather than to that of other remotely distant deserts. In spite of these differences of origin, there are manifold cases in which closely similar developments have taken place, both in structure and in performance, in such widely separated places as Arizona and South Africa, Turkestan and Western Australia.

The history of the four great lines of development of desert biota seems to be doomed to secure little aid from paleontology, on account of the unsuitability of arid conditions for the preservation and fossilization of living material. For the history of desert plants in particular there is little hope of enlightenment from the fossil record. The reconstruction of the steps in this great biological development must therefore be made almost wholly on the basis of the study of living forms.

The biological problems of the desert are concerned with the geographical source and phylogenetic origin of its organisms, the physical influences which have shaped their development, and the types of behavior and response which have resulted. Consideration of these problems in the light of their historical background emphasizes their unity and provides a frame-

work for the allocation and orientation of all investigative work looking toward an understanding of biological processes under arid conditions.

Throughout the history of the Desert Laboratory, its work has been devoted to the investigation of desert influences and the performance of desert organisms. There has been a growing tendency to view the processes of desert life as part of a vast development, originating in remote geological time, involving a very large number of races of plants and animals, and now occupying nearly one-third of the land surface of the earth as its theater of action. Past and current investigations have been concerned with small, but essential, details in the history of the movement of living matter away from the uniform moisture of the sea and the favorable moisture conditions of rainy regions, into the lands of small and irregular water supply.

The original aims of the Desert Laboratory are still being pursued (a) through the acquisition of a more complete knowledge of the desert region in which it is situated; (b) through the accumulation of physical data which from year to year give a fuller knowledge of the fluctuations and extremes to which life is subjected; and (c) through researches into the physiological behavior of desert plants, particularly with respect to their water economy.

#### DESERT EXPLORATION

Securing a better knowledge of adjacent desert regions is now much less costly of time and effort than in the early days of the Desert Laboratory. Field work is conducted with the dual aim of contributing to knowledge of the components of the desert flora and of studying the composition of the vegetation and the habitat requirements of its dominant plants. Work on the flora is conducted solely through collaboration, but the floristic records which are being maintained are essential to the work on vegetation.

For several years two expeditions have been made annually into the vast, thinly inhabited region southwest of Tucson. Records of rainfall in this area begun by Mr. Sykes have been continued by Dr. Mallery and extended to measurements of temperature extremes and certain soil conditions. As the rainfall data accumulate they are of rapidly increasing value, showing great seasonal fluctuations, highly irregular distribution, and some extremely low totals. The influences on the vegetation are being followed and have greatly broadened conceptions based on the somewhat more moist region near Tucson. Evidence has been secured that some of the plants, common to a wide range of rainfall conditions, make a more economical use of water in the drier parts of their ranges. It is believed that work on soil conditions which is now in progress will throw light on this surprising situation.

In April 1932, an expedition was made to the central districts of Sonora, affording an opportunity to compare certain physiographic and soil conditions with those of southern Arizona, and to extend knowledge of the vegetation about 200 miles south of the limit of previous exploration. Dr. LeRoy Abrams, Director of the Dudley Herbarium of Stanford University, joined this trip and collected over 400 plants, thereby greatly improving knowledge of the desert flora and its distribution in a region not so well known as that farther south.

The vegetation of Sonora is closely related to that of southern Arizona. The west coast of Mexico is the path along which many plant stocks have moved from the south to become a part of the desert flora of the United States. Few of the plants which have been investigated at the Desert

Laboratory can be fully understood without a better knowledge of their distribution and ecological behavior in the southern parts of their ranges. Several dominant woody plants undergo striking changes in their habitat requirements when followed for 300 to 400 miles southward. The gradual amelioration of winter temperature conditions is accompanied by the appearance of subtropical forms. Some of these are trees which bear every evidence of having a high water requirement, at the same time that they are able to flourish in areas with 6 to 10 inches of rainfall.

Living plants, seeds and material for anatomical study were secured both in such forms as *Larrea* (*Covillea*), *Fouquiera* and *Encelia*, already under investigation, and in other plants which promise to be of importance in the study of water relations.

#### ENVIRONMENTAL CONDITIONS

The paramount importance of soil moisture in the investigation of the water relations of plants has led to the continuation and extension of work previously reported in this field. A better understanding is sought of the entire chain of relations between rainfall and the actual supplies of water available to plants. The work on the ecology and physiology of non-succulent perennials, which has been the central interest for the past three years, has involved the necessity of extending knowledge of the moisture conditions of the soil to greater depths than have been investigated before at this laboratory. The root systems of these plants are much more deep-seated than those of the succulent perennials and annuals, for which the rainy seasons are alone important in the intake of water.

Mr. Turnage has made a tabulation of all rainless periods of more than two weeks duration as shown by the Laboratory records from 1907 to 1931, inclusive. Such periods have formed 55 per cent of the entire elapsed time during these 25 years, and six periods are indicated in which no rain fell for 100 days or more. Such a tabulation of extremes and their frequency is of importance in indicating the relative severity of current conditions.

During the year an automatic recording rain gage of the tipping bucket type has been installed in connection with the percolimeter, which makes it possible to interpret run-off readings in terms of precise knowledge of the duration and severity of each rain. Fortnightly readings of soil moisture at eight depths to 6 feet have been continued throughout the year in the alluvial soil of the Laboratory garden, the only type of soil in the region which is free from stones and hardpan and therefore suited to mechanical sampling. Seasonal determinations have also been made in coarse outwash, or bajada, soil on the western part of the Laboratory grounds, where it is necessary to make large excavations with pick and shovel in order to secure samples.

In the alluvial soil, great seasonal fluctuations in moisture content are found to a depth of 60 cm. Below this level increasingly stable conditions are found, and at 180 cm. the fortnightly march for 22 months exhibits great constancy at 15 to 16 per cent. During the most arid months, when the moisture content at 15 cm. fell below 5 per cent, the minimum at 180 cm. in 1931 was 15 per cent and in 1932 reached 14 per cent, a very low value for that depth. The heavy rains of November 1931 raised the moisture at 15 cm. to 24.3 per cent, and their effect was registered in the gradual elevation of the following readings at successive depths, the ultimate recognizable effect being at 150 cm. in January 1932. No change was found thereafter in the readings at 180 cm. Semi-annual extension of read-



ings at three additional depths to 360 cm. (12 feet) have given readings ranging from 13 to 17 per cent. This indicates that there is a layer of soil at least 8 feet in thickness, and probably much thicker, in which the moisture content is only slightly and very slowly affected by wet and dry seasons and in which there is at all times an adequate and safe supply of water for deep-rooted perennial plants.

The bajada soil on the Laboratory grounds is coarse in texture, full of small stones and underlaid by a thick bed of soft calcareous hardpan, or caliche, at a depth of 1 meter. It bears an open vegetation of *Larrea*, *Acacia* and *Franseria*. Four weeks after the close of the winter rainy season, moisture is distributed throughout this soil with remarkable uniformity to a depth of 270 cm. (9 feet), readings ranging from 5 to 7 per cent in the soil and from 6 to 9 per cent in the soft caliche. At the close of the spring dry period, moisture had fallen to 2 to 4 per cent in the soil but still ranged from 6 to 9 per cent in the caliche. Roots are abundant in the lowest level of the soil and a few of them penetrate the caliche. Under such conditions the soil contains no available moisture for plants in the dry season. Roots are able to penetrate the caliche with difficulty, but apparently secure some water which passes by capillarity from the upper level of the caliche to the lowest level of the soil. This view is suggested by the fact that the moisture content of the uppermost level of the caliche is lower in the dry season than the content at lower levels in it.

In all localities investigated, it has been found that the character and position of caliche is highly important in determining the vertical distribution of moisture in the soils which contain it. Experimental work on the rôle of caliche in the penetration, movement and evaporation of soil water, reported in Year Book No. 27, has recently been completed for publication. Further work with field conditions is necessary to test the conclusion that its presence retards penetration and reduces the water-carrying capacity of the soil at the same time that it aids in the retention of moisture in and below the layers which it forms. Its occurrence and relation to moisture conditions unquestionably have a selective influence in determining the composition of the vegetation.

The slowness of the changes in moisture content in alluvial soil has led to a study of the establishment of moisture equilibrium in bodies of soil of known initial differences in moisture content. In the preliminary experiments, large garbage cans have been used with two or three layers of soil made up to definite percentages and tamped solidly into place. Changes due to upward and downward movement of water are determined by borings made at intervals of 8 weeks. After 8 months there still exist such substantial differences in the moisture content of the various layers of soil as to indicate a much longer duration for the experiments than was anticipated. The results that are now indicated are of importance in explaining the conservatism of the moisture content of lower soil levels. Field conditions must not be interpreted too narrowly in terms of experimental work, however, owing to the existence of cracks, channels left by decaying roots, excavations made by rodents and other irregularities of soil structure which aid penetration.

The importance to plants of highly alkaline soils has long been well known. In field work conducted several years ago there were indications that relatively small differences in the total soluble salts were of importance in connection with the distribution of certain types of vegetation. More detailed work on the same localities cast serious doubt on this hypothesis.



Dr. Mallery and Mr. Humphrey began a series of total salt determinations in the summer of 1931, and data at one locality have been secured periodically by Mr. Hinckley for a period now extending over 18 months. In two localities determinations have been made at successive depths through borings made at 16 spots 1 meter apart, repeated seasonally by borings at spots only 3 cm. distant from the last ones. At another locality a continuous series of determinations has been made at spots separated at each boring by a distance of 2 meters from the last one. The data give a vivid picture of the very considerable differences in total salts which exist vertically and horizontally in the same body of soil, and the changes which are constantly taking place in the same vertical or horizontal section. It is manifest that in the case of plants with extended root systems it is impossible to do more than state the very wide limits of salt content of the soil in which they grow.

#### PHYSIOLOGICAL BEHAVIOR OF DESERT PLANTS

The work in physiology conducted during the past year has been mainly directed to the study of water relations in *Larrea* (Covillea), *Fouquiera* and *Encelia*. Work involving a comparison of transpiration, leaf water and wilting in *Larrea* and cotton is in its preliminary stages. The aim of these lines of work is to discover the mechanism of drought resistance in desert plants, and to determine the means by which they are able to persist under conditions which are fatal to the ordinary broad-leaved plant of high water requirement, of which cotton is an example.

During the year, Dr. Mallery has completed an investigation of the differences in the osmotic value of leaf sap of *Larrea* in four localities and has been able to correlate the range and rate of change of these values with some of the most important environmental conditions (see Year Book No. 30, p. 259). Weekly determinations were made of the osmotic value of the expressed sap of leaves and small twigs by the cryoscopic method, and concurrent readings were made of rainfall, soil moisture, total soluble salts of the soil, and the physical texture, chemical composition and wilting coefficients of the soils. In the four habitats investigated, the osmotic value was found to show differences in seasonal range, the greatest range being in the habitat in which the shrubs evinced the greatest vegetative and reproductive activity. Although rainfall exerted a strong influence upon the osmotic values through the medium of the soil, there were strong indications that some other factor, possibly the rate of photosynthesis, was more potent at times. A close correlation between the percentage of soil moisture and the osmotic value of the sap was found for changes of 0.25 per cent or more in moisture content of the soil at 15 cm. At the end of the rainy seasons the osmotic values approach the minimum (about 21 atmospheres) and are nearly equal in the different habitats. During extreme drought it was found that differences of as much as 8 atmospheres may exist in the sap of different bushes in the same habitat. A definite cycle of daily fluctuation in osmotic value has been found under all conditions.

Through the courtesy of Professor Franklin Crider, Director of the Boyce Thompson Southwestern Arboretum, Dr. Mallery has been able to make a series of determinations of osmotic value of several African and Australian desert plants. These had been under cultivation without irrigation at the Arboretum for two years, and sap was taken from them at the close of an unusually long, dry period. The general range of the readings

secured is from approximately 20 to 35 atmospheres, which is in close agreement with values obtained for such American desert plants as *Simmondsia* and *Dodonaea*. Values as low as 15 atmospheres were obtained for *Eragrostis curvula*, a South African grass, and 12 atmospheres for *Sterculia diversifolia*, a small African tree. Dr. Mallery hopes to be able to secure material of some of these plants from their native regions in order to be able to confirm the relative agreement between the osmotic values of plants of the same types which are native to different desert regions.

In the summer of 1931, Robert R. Humphrey began work on the unique water relations of *Fouquiera*, and is now engaged at the University of Minnesota in a study of the physiological anatomy of this plant and the allied *Idria*. These plants depart widely from the other desert shrubs which have been investigated, not only in the anatomy of their leaves, the rapidity of their appearance under favorable conditions, and their fall under unfavorable ones, but in the relation between the water of leaf and stem. The beginning that has been made in the investigation of these plants indicates that the small family of distinctively North American desert plants to which they belong has already made steps toward the development of a highly successful desert type intermediate between the non-succulent and succulent forms.

Ernest H. Runyon continued through the summer of 1931 his work on the leaf water of *Larrea* and is now preparing his results for publication. He has studied the daily fluctuations of leaf-water content as well as the seasonal ones and has compared plants well supplied and poorly supplied with water. He has used the "water deficit" of leaves, or the amount by which they fall short of their maximum water content, rather than the amount of water in terms of the dry weight of the leaf. He has demonstrated the dependence of growth on the water relations of the leaf and has found that growth of the young leaves of *Larrea* may be arrested for several weeks by drought and then resumed on the recurrence of higher water content. The seasonal fluctuations of water content in active leaves of *Larrea* are apparently greater than those reported for any other plant. The great fluctuations in water content in tissues of cacti have long been familiar, and it is of considerable significance to find in a non-succulent desert plant a similar high degree of accommodation to the frequent reversals of water supply to which they are subjected.

Dr. Fred W. Emerson, of New Mexico Normal University, spent two months at the Desert Laboratory in the spring of 1932, making the beginnings of an investigation into the effect of certain environmental conditions on the structure of the leaf of the composite shrub *Encelia*. Through cooperation on the part of the Desert Laboratory, Dr. Emerson will be able to continue his investigations during the coming year.

Dr. F. G. Gustafson, of the University of Michigan, spent five months at the Desert Laboratory investigating respiration in cacti, in connection with work which he has published on respiration in fleshy fruits. The extent to which cacti have developed epidermal features and stomatal behavior that aid in conserving their water has at the same time restricted the freedom of interchange of gases between the atmosphere and the intercellular body of gases within the plant. During the winter months Dr. Gustafson studied the anaerobic respiration of *Carnegiea*, *Ferocactus*, *Neomammillaria*, *Echinocereus* and two species of *Opuntia*, and also of *Verbena* and *Encelia*. Very little difference was found in the amounts of  $\text{CO}_2$  produced by plants in air and those in nitrogen. One species of *Opuntia* produced more  $\text{CO}_2$  in nitrogen than in the air. Most of the plants

were not injured by several days of anaerobiosis, while others were injured in a few spots. The leaves of *Verbena* and *Encelia* behaved very differently from the cacti. After 40 hours in nitrogen the rates of respiration in their leaves were reduced 14 per cent and 20 per cent, respectively, from their original values. These results indicate a great difference between the ability of the massive tissues of cacti and the thin leaves of other plants to endure anaerobic conditions.

A series of analyses was made of gas drawn from the interior of young giant cacti 2 to 3 feet in height. Samples were taken once or twice daily for 8 to 14 days and analyzed for CO<sub>2</sub> and O<sub>2</sub> concentration. From this limited series of analyses it is evident that the CO<sub>2</sub> concentration may become very high in the interior of cacti, while that of the O<sub>2</sub> may be very low. During the warmest months of the year it is probable that the CO<sub>2</sub> concentration is greater than here noted, and the O<sub>2</sub> reduced to the point of exhaustion.

#### ANIMAL LIFE

During the year the facilities of the Desert Laboratory have been extended to several investigators working on the animal life of the region. Mr. Clinton V. McCoy, of the Museum of Comparative Zoology of Harvard University, made a collection of reptiles in the vicinity of the Laboratory. Dr. Lee R. Dice, of the Museum of Zoology of the University of Michigan, a grantee of the Institution, spent several weeks in field work on small rodents. Mr. Victor M. Cahalane, Director of the Cranbrook Institute of Science, Bloomfield Hills, Michigan, a collaborator of Dr. Dice, spent three months in the study of the distribution of rats and mice in the mountain ranges of southern Arizona.

#### ECOLOGY

ADAPTATION, BY F. E. CLEMENTS, FRANCES L. LONG, EMMETT MARTIN, G. W. GOLDSMITH, GEORGE MERIDETH

The three major approaches to the adaptation of the specient are factor sequences, transplant gardens and field controls. As indicated previously, the first two have to do with placing the individuals under a range of natural conditions, while the third is concerned with modifying one or more factors in the natural setting. In consequence, the latter involves an actual area of the community, climax or seral, and serves to reveal in miniature the simultaneous response of specient and community to climatic or edaphic change. In all three attacks, the dynamics of adaptation are traced in detail by means of sealed and free phytometers of both standard and native plants. At present, the measurement of functional response deals chiefly with transpiration and osmotic relations on the one hand and with energy summations in terms of dry weight and calories on the other. The structural modification is followed by means of changes in stomatal number, in epiderm, mesophyll and vessels, and in the morphology of stem, leaf and flower.

#### FACTOR SEQUENCES

In attempting to disclose the factors involved in seasonal aspects and in the annuation of dominants and subdominants, often strikingly exhibited under a winter rainfall, dark tents have been utilized to secure exposure to different lengths of daylight. Such length-of-day series are also designed to afford an interpretation of the flowering behavior of alpine and plains species. In the transplant gardens, the former in particular have been



led to bloom in practically every month of the year, partly at the Alpine Laboratory and partly at Santa Barbara, with no evident relation to the length of day. In these tents, approximately 50 species have exhibited much the same relation found in the lath-houses with the light-intensity reduced to 12 per cent and 4 per cent of normal sunlight. The long-day cultures, *i.e.* the controls exposed throughout the day, regularly flower first and at a lower stature. The medium-day ones, with an exposure of 10 hours, blossom about a week later and at the greatest height, while the short-day flower last or not at all under an illumination of 5 hours. Again, as with the shade series, this was essentially an energy relation, as was indicated by dry weights and combustion values.

The use of soil-pits and soil-pans has been much extended, especially in connection with the dune gardens and with alkaline soils. The installation in the ridge garden consists of a blow-sand control and a pit each of sand from the shelter (*Lupinus*) garden, of garden soil, and of the latter with a 2-inch mulch of sand. In the shelter garden, the control and sand-pit are reversed, while in the experimental garden in Mission Canyon, loam is the control, with a series of blow-sand, shelter sand, and loam with sand mulch. For further comparison, there is also the regular soil series, consisting of fertile garden soil, ordinary loam, clay and river-sand. The soil-pans were designed to prevent leaching of the contained salts and were made of galvanized iron, 4 feet square and 1.5 feet deep. To each of these was added one of the following salts, in the amount of 0.5 per cent by weight, *viz*, sodium chloride, sodium carbonate, sodium sulphate, sodium phosphate, calcium sulphate and magnesium silicate. All individuals of the five species employed were dead in the first two after 4 weeks and more quickly in the chloride than the carbonate, while the best growth was in the soil supplied with the silicate. Striking differences in growth and modification were obtained in the dune series likewise, with corresponding light on the relative value of the several factors in the two gardens.

#### TRANSPLANT GARDENS

In a year of drought, the transplant gardens at the various altitudes from 6000 to 14,000 feet have yielded results in close correspondence with the water relations. Those receiving only the reduced rainfall have shown a marked tendency toward xeric types, especially dwarfs, and the alpine forms grown in them have retained their characteristic low stature. A similar result has necessarily obtained in the native communities, thus revealing the rôle of dry and wet phases of the climatic cycle in adaptation and foreshadowing the effect of major climatic shifts. An important consequence has been to confirm the view that water is an essential mechanical agency in modification and conversion, quite apart from its values as raw material and solvent.

In the semi-control gardens where the water-content is kept more or less at an optimum, modification is frequent and in the lath-houses almost universal. This may result merely in the production of shade types conforming closely to the various light intensities, or it may lead to conversion, either into a striking new form, into reciprocal intermediates between two contiguous species, or of one of these into the other, to the extent at least of the morphological criteria concerned. For this purpose, genera with several proximate "linneons" constituting a phylad furnish especially favorable material, as for example, *Erigeron*, *Mertensia*, *Senecio* and *Solidago*. Each of these is represented in the region by at least one phylad comprising



alpine, sun, shade, climax and seral species susceptible of conversion in more than one direction. Such modification seems readiest in the probable line of descent and with intermediate rather than terminal species. Thus, the basal *Mertensia sibirica*, apart from certain fluctuations or "small species" within itself, is least modifiable, and so far only in the direction of *M. pratensis*. The latter can be changed least easily in the reciprocal direction, but it and *M. lanceolata* are more or less regularly interchangeable. The most specialized species, *alpina*, can be brought to approximate *lanceolata* closely and the reciprocal conversion is likewise possible. *Erigeron*, with a comparable group of species, yields similar results in the sun-moist garden and in half-shade.

#### STOMATA AS INDEXES OF ADAPTATION

The value of the stomata as a ready index of adaptation is greatly enhanced by the stomatal film. The use of such collodion films for obtaining a quick and permanent record of the number and distribution of stomata promises to supplant entirely the method of epidermal strips, though this and direct vision will probably always remain indispensable for aperture studies. The collodion film, moreover, is applicable to leaves and upper surfaces not capable of being stripped, and it also avoids the obscuring effect of a torn mesophyll. Not the least of its virtues is the fact that an initial film can be employed to remove a coating of hairs and a new one then applied to secure the stomatal impression. Its rapidity and certainty of operation render stomatal transects, crosswise or lengthwise of the leaf, a simple matter, and thus permit much more comprehensive and accurate counts.

In the field, the collodion method was employed throughout the ecological reconnaissance from the Pacific to the Atlantic by a northern route and the return by a southern one. Many hundred paired-films were secured of climax and seral dominants and subdominants, with the twofold objective of determining the stomatal relations for life-forms and communities, as well as for genera. The large series of films and the range of communities gave a quasi-experimental value to the field studies and brought to light a number of novel correlations.

In the adaptation and transplant gardens, the use of films has become a standard method of great value and wide application. No other device supplies such a ready index to the course of adaptation and its final outcome. It holds the promise of forecasting correlations between the epidermis and mesophyll, and possibly of certain functional features as well. In addition to its ecological applications, it has much value in bringing together a much larger mass of information as to the number and behavior of stomata.

#### INSTRUMENTATION

The developing and testing of new instruments during the year have been chiefly restricted to the fields of solar radiation and of soil and aeration. The most interesting item in the former is the designing of the "holophot," which is intended to provide a summation of incident energy for any period desired up to a week in length. This comprises a photo-cell connected in series with condenser and battery so that the charge and hence the potential difference of the condenser accumulates on exposure to light. The condenser is connected to a grid-glow tube, in such manner that a discharge current is set up in the latter when the potential difference reaches a certain value, and this actuates a relay and counting device.

The rate of building up the potential determines the number of impulses per unit time, but itself depends upon the photo-electric current, which in turn is proportional to the rate of energy reception. In consequence, the number of impulses recorded for a given interval of time is a function of the amount of energy falling on the photo-cell. Since the rate of building up potential varies with the capacity of the condenser, it becomes possible to secure a wide range of recording by employing a large condenser for high and a small one for low intensities.

The power consumption is approximately 5 watts at 5 volts, thus permitting the use of dry cells for operation at considerable distances from the base laboratory. The four instruments constructed have been calibrated against the pyranometer and then installed successively for readings in three different series, namely, one from climax grassland at 6000 feet to alpine tundra at 14,000 feet, another in climax and seral habitats of the montane forest at 8000 feet, and the third a combined series of the two.

CLIMATE AND CLIMAXES, BY F. E. CLEMENTS, E. S. CLEMENTS, H. L. SHANTZ, B. C. THARP, V. E. SHELFORD, C. K. COOPERRIDER, W. P. TAYLOR

CLIMAXES OF NORTH AMERICA

In furthering the investigation of climax formations, several briefer trips have been made into the deserts and sierras of California and to a number of alpine summits of Colorado. The most extended journey has traversed the continent from the Pacific Coast to northern Michigan, Ontario and New England, and thence to the Everglades of Florida, returning along the Gulf Coast and through the Southwest. In its course, special opportunities were made for visiting several of the highest peaks of New England and the southern Appalachians. This was the third motor tour through the East, and in consequence it was possible to check the earlier observations repeatedly and to extend them widely, especially in terms of comparative details.

Among the major objectives were the further study of the ecotone between deciduous forest and grassland in the Middle West, and of that of the pine-hemlock forest with the boreal climax on the north and the deciduous on the south. Particular attention was paid to the climatic and edaphic relations of the three associations of the deciduous forest and to their respective ecotones, especially in the mountains. A preliminary attempt was made to outline their faciations and lociations and to correlate their structure and development with the major climatic cycles of the more recent past. Probably the most interesting community encountered was the magnolia-bay hammock, observed in many examples throughout central and northern Florida. These have been so much restricted and modified by fire as to render their interpretation difficult, but all the evidence indicates that they are postclimax relicts, now embayed in the southernmost faciation of the oak-hickory forest.

During the past decade of field work, much attention has been given to the grouping of dominants within the association, particularly in the mixed prairie. This not only possesses the great advantage of all grassland in revealing structure more clearly than forest or scrub climaxes, but also the further one of being the most complex and varied of the five prairie associations. In 1920, the term *faciation* was suggested for the major subdivisions of the mixed prairie, and *lociation* for the more localized groupings within these. A few years ago in outlining the plan for the "Climax Formations of North America," a list of faciations was drawn up on the

basis of existing knowledge, and this has been subjected to constant test in the field since that time. With this has gone the endeavor to sketch in the locations and to relate them to the climatic features and history of the regions concerned.

#### FIRE AND GRAZING SUBCLIMAXES

The autumn of 1931 was probably unsurpassed for the opportunity afforded of studying the effect of fire in forest and scrub communities, especially in the South and Southeast. In the latter particularly, it was necessary to travel for several days in a thick pall of smoke, with active fires at intervals of a few miles or less. While the pine forests, from the barrens of New Jersey to the woods of eastern Texas, had already been recognized as fire subclimaxes ("Plant Succession and Indicators," p. 187), this was on the basis of successional evidence and the study of similar pine communities in the West. Consequently, direct observation of the extent to which fire is a controlling process in a region long-settled leaves no doubt of its practically universal operation through several centuries at least. Wherever a measure of protection was to be found, the climatic hardwoods were regularly in evidence, the dominance of pine or the degree of mixture affording a scale by which to estimate the frequency of fires. Even the pines themselves are sorted out by the same process, *Pinus palustris* in particular enjoying an effective immunity by virtue of its seedling habit and long dense needles.

On the high mountains of North Carolina, such as Grandfather Peak and Mount Pisgah, as well as others of the Appalachian chain, recurrent fires have exerted an even more striking effect. This is the more or less complete elimination of trees and the production of a subclimax composed almost wholly of heaths. Such "heath-balds" are the ecological equivalents of fire chaparral on the Pacific Coast; not only is the course of succession practically identical, but the presence of fire-scars and of charcoal in the soil confirms the rôle of fire. Likewise, "grass-balds" are regularly if not always of fire origin; they may be held in this earlier stage by greater frequency of burning, or may result from the conversion of heath-balds by fire. An instance of the latter by a fire of the season was studied in detail on the shoulder of Grandfather Peak, and the fire-margins of much larger grass areas were investigated on Mount Pisgah, as well as the stages of the subere concerned.

In the Rio Grande peninsula, as well as in south-central Texas generally, the vegetation bears the appearance of an extensive scrub climax of *Prosopis*, *Acacia*, *Condalia* and their associates. Actually, however, this is a savannah of the coastal prairie, in which fire and overgrazing have cooperated to favor shrubs at the expense of the climatic grasses. In the neighborhood of Falfurrias, several large stretches of original coastal prairie with little or no mesquite were found, their persistence having been favored by infrequent fires and moderate grazing. The shrubs owe their victory over the grasses chiefly to the ability to sprout from the roots after a fire, but two coactions also play a very important part—the reduction of grass competition through grazing and the distribution of such hard seeds as those of the mesquite by cattle. The mesquite country in consequence is to be considered a savannah postclimax due to fire and grazing.

#### BIO-ECOLOGY

Further investigation of the relations of dominant plants and influent animals in the land biome have confirmed the assumption that the unity



of the latter rests primarily upon the numerous inherent coactions between the two groups of organisms. While this signifies that the ranges of the influents will fall largely within the climax matrix constituted by the dominant plants, the fact that the former are motile is sufficient explanation of their occurrence in contiguous climaxes, to a considerable extent at least. Moreover, since plants are the food-makers of the biome, their dependence upon climate is much more direct and intimate than that of animals, and hence they are clearly more important indicators of climate. Furthermore, they lack the internal regulatory mechanisms of animals, while the latter are also favored by a wide variety of shelter coactions and reactions. Finally, plants have a profound effect upon the ece through the universal process of reaction, a rôle that is of much slighter importance in the case of land animals. On the other hand, coaction as an active process is largely controlled by animals, a fact recognized by the term influent.

The gradual shift in the relation of organisms to climate is well illustrated by the various categories. Dominant plants receive the full impact of the climate, and hence are the paramount indicators of it, in terms of a climax. Subdominants respond to a climate modified by the dominants, moderately so in the case of grassland and more or less profoundly by the canopy of a forest; they are less important climatic indicators and play a secondary rôle in the climax. Influential animals resemble subdominants in living in a climate modified to some degree by the dominant plants, especially in forest and scrub, but they have no such direct relation to the physical factors of the habitat. They may also be further withdrawn from the action of climate by means of shelter devices and especially by hibernation, estivation or diurnation. The kangaroo rat of the desert, dwelling in deep burrows by day and active only at night, demonstrates how effective such removal can be. Subinfluents, especially seasonals, may extend through several different climates and climaxes, a relation exemplified by a number of butterfly and bee pollinators that range from the plains grassland to the alpine tundra of Pike's Peak.

#### GRAZING RESEARCH

A summer marked by ample rain and a winter of exceptional snowfall have aided materially in explaining the lack of harmony between the research exclosures at Seligman and Williams in northern Arizona. The latter has been constantly in accord with the principles laid down in "Plant Indicators" for the recovery of overgrazed range under protection, namely, that the tall-grasses would gradually return and that their competition would slowly but surely kill out the undershrubs, such as *Gutierrezia* and *Chrysothamnus*, and relegate the short-grasses to the rank of a secondary layer. At the Seligman exclosure, however, relatively slight progress has been made in fifteen years of protection, apparently constituting a distinct exception to the rule. It had become evident that the failure of the tall-grasses to return was due to their almost complete disappearance in the vicinity and that the absence of successional movement in the extensive areas of annual weeds was due to recurrent surface wash. The latter process was much more in evidence this year than ever and left no doubt that the progress of the subseres toward the short-grass cover would be contingent upon diverting flood-waters, as is now planned to do. It was further learned that the grazing pressure, both of cattle and rodents, was much less than at the outset and that consequently no great difference between range and exclosure units could be expected.



This area also furnished fairly decisive proof of the growing feeling that rodents and ants enter grassland in large numbers only in consequence of overgrazing, surface erosion and similar disturbances. This is largely in consequence of more succulent food, the forbs especially being more abundant, but it is apparently related also to the disappearance of the tough sod and the general loosening of the soil. The preference of prairie-dogs and chipmunks in particular for forbs in contrast to grasses had been determined by means of clip quadrats at the outset of the studies and is readily explained in arid regions by the greater sap-content of the forbs.

### CLIMATOLOGICAL RESEARCHES

By A. E. DOUGLASS

#### COAST REDWOODS

A study of Coast Redwoods for their ring records was made in the summer of 1931. Previous work on two groups, namely, Santa Cruz in 1922 and Scotia in 1925, failed to develop that cross-dating which has been considered a preliminary to climatic interpretation of ring widths. An inspection was made of the groves from north of Crescent City, California, to south of Monterey. It was seen at once that basal sections such as stump tops, found very acceptable in other trees, are defective in this species, due perhaps to the slenderness of the lower part of the trunk. Numerous "wind checks" resulting therefrom produce erratic growth in the recovery rings. This effect decreases in the upper part of the tree; hence collection was made from three different levels in each tree in order to study this matter and cross-dating between the upper parts of trees has been successful, though it is not yet as satisfactory as in the pines of Arizona or even in the pines of the High Sierras of California.

The problem of the limitation of the habitat of the Coast Redwood is a most important one in connection with the interpretation of its rings. Its relation to the fogs on the coast of northern California certainly suggests that from its rings we may eventually extract a history of fog intensity on that coast. That in turn leads us to the study of changes in terrestrial winds and ocean currents. It also calls our attention to the lack of adequate records of fog intensity and of instruments with which to make such records.

#### CLIMATIC INTERPRETATION OF TREE GROWTH

These studies in the coast redwoods have assisted in formulating a little more definitely certain principles underlying tree-ring studies. They may be stated as follows:

If many independent trees in a forest, over a wide area and for a long interval of time, show similar ring variations in identical years, the cause of such variation is climatic, because climate is the common continuous factor in their surroundings.

A forest border dependent on certain topographic features, such as altitude or latitude or coast line, becomes an important guide in the search for the particular climatic element that is influencing the trees, because that element is emphasized in border trees.

#### CYCLE STUDIES

Perhaps the chief movement in climatological research in the past year has been the increased emphasis placed on the study of cycles. During the early years devoted to tree-ring studies, attention to this phase could

be given only occasionally. The obvious need for cycle analysis resulted in the development of the cyclogram method in 1913 and the construction of an automatic cyclograph in 1914. This method has been described elsewhere in detail and need not be given here. Its technique has been gradually developed by years of application to the long records contained in tree rings. Its essential and unique characteristic is that in a pattern called the cyclogram, the beginning and ending of discontinuous and variable cycles may be seen. Nearly all the work can be done by student help, and results may usually be obtained by a brief examination of the pattern either in the instrument or in a photograph.

During the past year extensive analysis has been made of accidental sequences. For this purpose the values measured in a given sequence of rings were twice drawn by lot and plotted and the curves analyzed. The question was raised whether it would be possible to distinguish the genuine from accidental curves of this sort by the cycles. In some 20 different natural sequences so tested, no failure was made in selecting the genuine from the accidental curves. The average number of the units in the sequence was 175. When this number fell below 100, success was much less certain. However, it was felt that there had been no question of distinguishing the genuine in sequence of 150 or more years in length. The difference between the genuine and accidental consists in the greater average cycle length in the genuine. In other words, the periodogram of an accidental series consists of a descending curve while that of a natural series has a horizontal or an ascending line as the length of cycle increases.

Two developments of cycle study of tree growth may be noted. First, analysis tests are being made of synthetic curves in which a series of unknown discontinuous cycles have been combined by an assistant for resolution by the cyclogram method. This is working out in a very interesting and satisfactory manner. The other development is a complete review of work done on the big sequoias and the analysis of those long and valuable sequences. Evidence is appearing of recurrence of certain cycles in long periods which gives us an approach to what might be called "cycle succession."

#### CLIMATIC RECORD IN THE SOUTHWEST

An attempt is being made to extend to earlier years the climatic and prehistoric record which now reaches 650 A.D. A group of three superb beam sections in charcoal has been discovered and skilfully preserved by Mr. Earl H. Morris in an early ruin near Johnson Canyon. These give a clear record 350 years long whose actual dating has not yet been satisfactorily determined.

#### STAFF

On July 1, 1931, Dr. Waldo S. Glock, of the Ohio State University, joined our staff as full time assistant. During the year he has made a careful study of the pinyon sections obtained by Morris at Mummy Cave in 1927; also, of the large Morris collection of post Basket Maker material from the Lukaichukais in 1931; he has taken up the technique of preparing and mounting and measuring tree record material; he has done the clerical work on the investigation of the Sequoia records, and has produced a dozen synthetic curves for analysis by the writer. Mr. H. F. Davis has given special assistance in measuring Coast Redwood records, in extensive work on measuring petrified wood from Yellowstone, and in

photographic work in connection with cycle analysis. Mr. C. G. Keenan has assisted in mounting the large Coast Redwood specimens.

## PALEOBOTANY

RESEARCHES BY RALPH W. CHANEY

During the past year, emphasis has been placed on field and laboratory studies having to do with the relations of the early Tertiary floras of western America and the living forests of Central and South America. Large numbers of herbarium specimens have been compared with the fossil leaves, and field work has been carried on as described more fully below. Our conclusion is that during the early days of the Tertiary, a northward movement of plants from the tropics resulted in the extension into Oregon of a forest like that now living from Mexico down to northern South America; judging from the distribution of its modern equivalents, this forest was not strictly tropical, but had more the character of the vegetation on the middle mountain slopes and can be termed a temperate rain forest. Cooling during the middle and late Tertiary has resulted in the restriction of this forest southward to its present range.

The continued study of Tertiary floras indicates the importance of the plant record to the problems of earth history in western America. Much is being learned regarding the taxonomic composition, centers of distribution and physical significance of the fossils themselves, but the stratigraphic sequence of the formations in which they occur is inadequately known, and the relations of these formations to the standard sections in other parts of the world are often too little understood. The common occurrence of determinable plant material in series containing marine invertebrate faunas, and the fact that the same fossil plants also occur in typically terrestrial deposits which include a record of land vertebrates, places the floral evidence in the position of correlating the marine and terrestrial sections, and of cross-dating the record of sea life with that of the land.

An example of the inadequacy of our knowledge of the stratigraphy of western America is the present doubtful position of the Oligocene in its relation to the underlying Eocene and the younger Miocene deposits. Work now in progress on the older Tertiary floras will do much to establish this section in relation to standard sections elsewhere; the principal projects under way, some of which are nearing completion, are being carried on by R. W. Chaney and E. I. Sanborn on the Goshen flora of Oregon, by R. W. Chaney on the Clarno flora of Oregon, by R. W. Chaney on the Sooke flora of British Columbia, by E. I. Sanborn on the Comstock flora of Oregon, by R. S. LaMotte on the Tejon flora of Washington, by H. D. MacGinitie on a flora from Hayfork, California and by Susan Potbury and by R. W. Chaney in the auriferous gravels of California.

Unlike the middle Tertiary floras of western America, these older fossil assemblages have a composition which has little in common with the modern forests of temperate America, but which shows a close relationship to many of the forests of Central and South America. During the months of January and February, accompanied by Erling Dorf, the writer visited the lowland tropical forests of the British West Indies, British Guiana, Venezuela, Panama and Guatemala, and the temperate rain forests on the middle slopes of the mountains in Venezuela, Costa Rica and Guatemala. Here there were observed many of the modern equivalents of the older



Tertiary species of western America, and a study of the floral composition of these forests and of the conditions under which they live, has made it possible to interpret certain of the fossil floras in terms of their surviving elements in the neotropical region.

Of critical importance in establishing the routes of migration over which our floras have passed is the occurrence of fossil plants in South and Central America. This aspect received little emphasis during our trip of the past winter, but further collections in that region may be expected to greatly amplify our knowledge of the sources of many of the elements of the Tertiary floras in western America.

H. L. Mason is completing his study of the Pleistocene vegetation of the Tomales Bay region, California. Approximately 50 species have been recognized, all of which are still living in the coastal flora of California from Monterey to Mendocino Counties. This group of plants indicates a climate not unlike that of Tomales Bay today.

A small piece of charred wood has been sent in by Dr. Davidson Black from the Pleistocene deposits at Chouk'outien, from the same locality in which the remains of *Sinanthropus pekingensis* have been collected. It has been identified as *Cercis* by L. H. Daugherty, and appears to be closely related to a species of redbud still living in this part of China. Other specimens of wood have been collected, and a study of them may be expected to indicate the nature of the forest in which the early human inhabitants of Asia lived.

## CYCADEOID INVESTIGATION

RESEARCHES OF G. R. WIELAND

Because of the notable accessions of new petrified cycadeoids during the past five years, it is now found necessary to narrow the investigations under way sharply and to confine them for some time to come to the North American petrified series alone. By this is not meant any restriction of needed field work; and attention is called to the fact that the description of the fine Isle of Wight specimen mentioned last year is now virtually complete, as is also the sectioning and a fairly adequate account of the Dresden *Raumeria*. While likewise, the subsidiary study of the Cerro Cuadrado (Patagonia) araucarians is now in the hands of the Field Museum staff for consideration or needed examination preceding publication. This study has taken the form of an extended memoir in which is included a long-needed view of the possibilities of a fundamental relationship between cone and flower-bearing seed plants.

Therefore, the attention of other investigators is called to the general fact that the immense non-petrified Mesozoic cycadophytan record of both North and South America is at present receiving but the scantiest attention. Both field and laboratory study brought up to present-day requirements and methods is a very great need here; and here it is that further discovery bearing on the older history of the angiosperms is most likely to be made. Most of the work on this major subject which has so far appeared requires either revision or extension, and in making such a statement it is not wished to exclude my own volume on the singularly rich cycadeoid floras of the Mixtecan region of Mexico. Just now the foreground has here been cleared by a quite thorough paper on the left-over Tertiary cycadeous vegetation of North and South America brought out by Dr. Hollick.



## CYTOLOGICAL INVESTIGATIONS

BY JOHN BELLING

The study of the earliest diplotene in *Lilium* and *Fritillaria* has shown that there was no sliding of the chiasmata, or opening of the secondary split, at the nodes examined. This can only be determined when the chromomeres have been well fixed. The statements of authors who have not fixed the chromomeres seem to lack weight.

The measurements of internodes at early diaphase were thus not affected, or only affected to an unimportant degree, by sliding of the chiasmata in *Lilium*; and hence may be regarded as a demonstration of the interference of chiasmata.

The writer's results with the leptotene chromomeres of flowering plants have again been checked, and the preparations also studied with the monobromide of naphthalin objective of 1.6 aperture; his studies of the appearance of the secondary split at pachytene have been extended to other plants; and his demonstration of the single nature of the chromonema in the living metabolic nucleus has been repeated with other plant material. All these lead to the conclusion that the chromonema is not normally split in the resting or in the leptotene nucleus, and that appearances to the contrary are artifacts of fixation *en masse*.

The writer's hypothesis of crossing over and interchange has been able to explain all the data so far tested, including facts which certain authors have not been able to fit into it.

The writer has found that placing slides, stained with iron-brazilin and mounted in cedar immersion oil, in direct sunlight, affords the best known method of destaining them to exactly the required degree.



# DEPARTMENT OF TERRESTRIAL MAGNETISM<sup>1</sup>

JOHN A. FLEMING, ACTING DIRECTOR

## GENERAL SUMMARY

The death on April 12, 1932, of Louis Agricola Bauer, Director from 1904 and Director Emeritus from 1930 of the Department, removed from science an internationally recognized authority. Largely through his enthusiasm and organizing ability, based on his earlier work in the magnetic survey of the United States Government, the systematic magnetic survey of the whole Earth, sponsored by the Carnegie Institution of Washington upon his initiative, was accomplished. This survey established the empirical basis of required accuracy for theoretical discussions of the origin and behavior of the Earth's magnetic field. Bauer was among those foremost in the discussion of terrestrial magnetism and of related geophysical problems, as is evidenced by his many scientific contributions. No small part of the international coordination of research in geophysics during the past forty years may be attributed to Bauer's devoted efforts. His was an increasingly important directive influence in the progress of terrestrial magnetism throughout the period of his active labors.

As in the preceding year, the year July 1, 1931, to June 30, 1932, was given over largely to the statistical investigations of the accumulated observational material and to the development of the possible laboratory attack on problems in terrestrial magnetism and electricity.

The discussion by Bartels of magnetic correlations with solar conditions utilizing all available data was completed. It is concluded from this discussion that there must exist in the Sun's surface certain restricted areas (*M*-regions), the lifetime of which is limited (up to a year), though generally longer than that of sunspots. They cause terrestrial-magnetic disturbances, very likely by emitting well-defined corpuscular streams. These solar regions, as individuals, escape the usual astrophysical means of observation (visual, photographic, and spectrohelioscopic); they can as yet only be traced in terrestrial-magnetic activity. Terrestrial-magnetic records have therefore obtained a purely astrophysical interest, beyond their well-known geophysical aspect, namely, the indication of the times when the Earth is actually under the influence of solar streams.

The investigation on the diurnal magnetic variation on selected quiet days was continued. The large material derived from harmonic analyses is ready for discussion, which will supplement, from a different view-point, the research into the variability of solar influences as indicated by magnetic activity.

Much attention was given the characteristic features of terrestrial-magnetic research, which are common to other branches of geophysical research, in comparison with those of laboratory physics. While the impossibility of keeping the relevant conditions of observation constant leads naturally to the use of statistical methods in geophysics, the policy of the Department, adopted over fifteen years ago, of effecting laboratory approach

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to its problems finds increasing justification in the rapid development of physics and astrophysics.

The deliberate attempt to provide a new means of attack on some of the most basic problems in magnetism and physics, by the development of artificial (high-voltage) sources of high-energy particles and radiations, undertaken by the Department in 1926, has been finally carried to a point where the technical difficulties have been overcome and its development as a research-tool has been largely completed. The next stage, that of its effective application to specific problems, is now under way.

During the report-year the remaining difficulty, as emphasized in previous annual reports, of providing an inexpensive source of steady high voltage to replace the spark-excited Tesla coil has been surmounted. Tests of a 2000-kilovolt Van de Graaff electrostatic generator, constructed at the Department, show it to be a highly suitable voltage-source for these experiments.

Using the Tesla coil and a "flashing" tube in connection with a Wilson cloud-chamber, first observations were made of the range in air of 1100-kilovolt protons. A systematic search for disintegration-phenomena was undertaken, but the technical limitations of the Tesla-coil equipment in these experiments showed that they might better be postponed until the Van de Graaff generator was installed. Meanwhile, steady progress was made on the program of developing instrumental techniques for new observations and measurements of basic importance using the high-voltage technique.

Assurance of additional data much needed in the polar regions for the extension of the Gaussian spherical harmonic analyses of the Earth's magnetic field was given by the definite provisions made by numerous governments and private organizations to participate in the International Polar Year program of 1932-33. The efforts of our Department have helped the realization of this program: (1) In presenting the subject and in securing favorable Congressional action for participation of the United States in the full geophysical program during the Polar Year at a proposed College-Fairbanks station in Alaska; (2) in expanding the program at our Watheroo and Huancayo observatories; (3) in effecting arrangements for special magnetic and auroral observations at Point Barrow, Alaska; (4) in enlisting the interest of the American Telephone and Telegraph Company which is establishing earth-current stations at four places in New York, Maine, Illinois and Arizona; (5) in making earth-current equipment available for the Canadian station at Chesterfield Inlet, besides furloughing Davies of our staff, upon the request of the Meteorological Service of Canada, to take charge; (6) in providing two observers and much equipment for the work to be done at the College-Fairbanks station; and (7) in loaning a magnetometer-inductor for use at the Cape Town station.

The results to come from the Polar Year stations will be valuable also in secular-variation investigations. This year an especial effort was made to secure magnetic observations at repeat-stations over much of South America, since the results of our previous work have shown the secular variation to be of unusual interest on that Continent. Not only do the annual rates in all the elements differ greatly from place to place, but their accelerations (positive or negative) are everywhere varying so rapidly as to require a



repetition of observations at short intervals to provide the requisite continuity of information by which the changes of the magnetic field may be adequately defined.

Important results have been obtained experimentally in the study of the factors and laws determining ionic balance in the atmosphere and its relation to atmospheric pollution.

The magnetic, atmospheric-electric, earth-current and meteorological programs at the Watheroo and Huancayo observatories, the atmospheric-electric program in the Deck-Observatory in Washington, and the cooperative work in atmospheric electricity with the Apia Observatory of the Department of Scientific and Industrial Research of New Zealand, and in atmospheric electricity and earth-currents at the Tucson Observatory of the United States Coast and Geodetic Survey, were maintained. Seismological and radio observatories were built at Huancayo, radio power-equipment and a vertical-component seismograph were installed, and two horizontal-component seismographs were shipped for installation. Spectro-helioscopes loaned by the Mount Wilson Observatory were installed at the Watheroo and Huancayo observatories.

The reductions and compilations of the work in physical and chemical oceanography and in marine meteorology from observations made during the last cruise of the *Carnegie* were continued and the compilations and discussions were well advanced. Cooperating agencies also report good progress in the examination of bottom-samples and of biological samples.

The Department's policy of cooperating with other investigators and organizations interested in its geophysical researches was maintained. This was particularly the case, not only in endeavors to increase the magnetic secular-variation material so urgently required, but also in the field of atomic and nuclear physics.

## INVESTIGATIONAL AND EXPERIMENTAL WORK

### TERRESTRIAL MAGNETISM AND ELECTRICITY AND COSMICAL RELATIONS

#### *Correlation of terrestrial magnetism with solar and cosmical phenomena—*

The statistical relations between terrestrial-magnetic activity and solar activity were discussed by Bartels in several ways to find a physical interpretation. In agreement with general statistical considerations, the correlation between magnetic and solar activity appears to grow with the length of the intervals which are compared. Thus, annual means show good parallelism in the 11-year cycle, while monthly means show less correlation, especially in the descending phase of the 11-year cycle. New insight into solar influences on magnetism was obtained by means of a graphical day-by-day record of magnetic activity (represented by the international magnetic character-figures) for 1906-31. This diagram was originally devised for demonstration of the well-known fact that quiet as well as disturbed times in terrestrial magnetism tend to recur after about 27 days, that is, the approximate period of the Sun's rotation; this phenomenon had formerly been studied by taking averages for many rotations. The new record allows one to trace definitely every 27-day recurrence-sequence and,

above all, to compare the individual magnetic sequences with the corresponding phenomena in solar activity. The result of this comparison is surprising in that pronounced long-lived 27-day recurrence-sequences in terrestrial magnetism have no counterpart in the direct astrophysical observations of solar phenomena. The investigation shows that photographic records from observatories registering variations in terrestrial magnetism may determine solar activity through the restricted solar regions they identify and which we have designated *M*-regions.

McNish tested the reliability of the 8-month and 11-month periodicities of the solar constant, described by C. G. Abbot, by the harmonic-dial method of Bartels for the 88-month interval beginning September 1, 1923, over which these two periodicities are orthogonal. It was found that both periodicities may be represented to within the probable error of the smoothed values by a single trigonometric term. The probable error of a single wave of both the 8-month and the 11-month periodicities is greater in each case than the mean value of the amplitude of that periodicity over the interval investigated, although the mean value of the amplitude in each case is sufficiently great in comparison with its probable error to indicate that the periods may be valid. The uncertainty of the periodicities is so great, however, that it warns against using them in attempting to predict magnetic or other terrestrial phenomena.

*Magnetic activity*—Duvall continued his study of the new measure of magnetic activity (*Caractère Magnétique Numérique des Jours*). The final results of the new measure for Watheroo and Huancayo for the years 1929, 1930 and 1931 were completed. Discussion of the results for 1929 and 1930 showed the new measure to have a characteristic seasonal change.

*Magnetic diurnal-variation and current-system of the upper atmosphere*—A spherical harmonic analysis was begun by McNish of the anomalous magnetic diurnal-variations of the Western Hemisphere, which indicates a current-system of the upper atmosphere considerably different over that region from the idealized system deduced by Chapman. This analysis accurately defines this system and maps its lines of flow. Magnetic diurnal-variations from the records of those observatories situated near the 75th meridian west of Greenwich are being used in this analysis. Harmonics of higher degree may make possible an accurate representation of this anomaly.

*Atmospheric pollution and its relation to atmospheric ionization*—In our atmospheric-electric studies during the past fifteen years, measurements of potential gradient and of conductivity received greatest attention. Emphasis has been placed on the character of the variations in these elements and upon securing some idea of their absolute values, rather than on procuring answers to the question of why the variations behave as they do. The small ions in the atmosphere are responsible for the conductivity and variations in their number bring about corresponding variations in conductivity. The change in the number of small ions is caused by variations either in their rate of production or in their rate of removal. The present investigation deals with variations in the rate of removal of small ions from the atmosphere which results when they become attached to large ions and to condensation-nuclei. The studies, therefore, have included observations on the number and nature of these nuclei or particles.

From observations by Wait and Torreson at the Laboratory in Washington, it was found that, in general, the mobility of the large ion here is greater than that found by other investigators. One method of investigation showed 72 per cent of the condensation-nuclei to be uncharged, while another quite independent method showed 28 per cent to be charged, half positively and half negatively. Thus it appears all condensation-nuclei are capable of becoming large ions. Upon this basis the recombination-coefficient between small ions and large ions is five times the value of the coefficient for small ions and uncharged nuclei. The results justify for purposes of computing the rate of ionization the use of the equation now accepted as representing the equilibrium-condition between that rate of ionization and the rate of removal of small ions in the atmosphere.

An appreciable diurnal variation in the rate of ionization would hardly be expected from consideration of the ways in which small ions may be produced in the atmosphere. However, the calculated rate of ionization showed a systematic and large diurnal variation. The first results were based upon eye-observations. These have now been supported by others based upon extensive and continuous registrations obtained with photographically recording apparatus. While this diurnal variation may be real, it must await confirmation by direct measurement before final acceptance.

Several months of continuous recording of large ions were obtained before the end of the year. A preliminary analysis of the data has shown a change in the character of the diurnal variation with time, suggesting that other sources than merely products of combustion must be considered.

*Upper-air and radio research*—The study of terrestrial-magnetic variations and of the possible effects of such variations on radio waves and their relation to ionizing agents are sources of chief promise for information about the physical state of the outermost layers of our atmosphere and, thereby, about cosmical influences on the Earth. The compilation of lunar diurnal-variations at our two observatories, now well under way, must be expected to give data bearing upon the ionized regions of the upper atmosphere.

Observational data on the variation in height of these ionized regions (Kennelly-Heaviside layer), following the development of the echo-method of determination initiated in this Department in 1925, are now being obtained regularly by the United States Bureau of Standards. Apparatus has been designed in cooperation with the Bureau of Standards and is being constructed in the instrument-shop to record these variations at Watheroo and Huancayo—such work at the latter Observatory is especially desired because of the unique conditions set up by present theories of the ionized regions and of auroral phenomena in the equatorial belt.

Greenleaf W. Pickard, research associate, reports on continuation of the systematic recording of radio transmission at Tufts College, Massachusetts, and at Pasadena, California, under the direction of G. W. Kenrick and Howell C. Brown. Feeling that the question of a lunar period in radio transmission required further study, Pickard devoted much time to harmonic analysis of all available reception-series in an attempt to determine the reality of this period. As the result of an analysis of ten years of Austin's day fields from European stations, six years of night fields from



WBBM, five years of Pasadena night fields from San Francisco, and four years of the WCI records, he believes he has somewhat strengthened the case of the existence of a lunar period, although his analysis has also shown that in general the amplitude is small.

Professor A. E. Kennelly, who continued as research associate, prepared a paper dealing with cosmic disturbances of terrestrial magnetism and their influences upon radio communication.

*Magnetic work at sea and instrumental investigations and improvements*—Satisfactory experiments have been made with the automatic swing for the detection and measurements of centrifugal couples of dummy compasses subject to ship's rolling motion. The theory has been investigated by Peters and the comparison of theory with experiment in general is fair. There remains a discrepancy in the magnitude of the deviation which has yet to be accounted for probably by the differences in the conditions of the experiments and the assumptions made in the theory. The investigation, however, has proceeded far enough to begin experiments with various types of compasses. Experiments with the automatic swing are yielding valuable information on the probable behavior of compasses subjected to ship's motion. They suggest the possibility of correcting for such effects, at least to some extent, the magnetic results already obtained by the Department at sea. The investigation also suggests that ship's compasses in general might be improved by a more careful distribution of mass in the compass-card according to definite specifications. The examination by Peters of a number of compasses seems to indicate that some makers have overlooked the real import of the specifications for compass-magnets as regards the moments of inertia, probably because the specified arcs refer to an imaginary circle. This work has already suggested improvements for the marine collimating-compass designed by Peters and used for so many years on the *Carnegie*.

Various solutions to the problem of making magnetic observations at sea in cooperation with expeditions that might employ vessels or dirigibles of ordinary construction have been and are still being considered. Soule designed a reactor for experimental work on an earth-inductor method of measuring magnetic intensity from a moving support and prepared preliminary design for a remote reading-instrument to determine magnetic dip and intensity at sea.

*International Polar Year and polar magnetic data*—To meet in some degree the need of reliable data for the extension of the Gaussian harmonic analyses of the Earth's magnetic field beyond the 60-degree parallels of latitude, much time was given to securing participation of the United States in the International Polar Year program for 1932-33 and to preparation of plans and equipment for use at Polar Year stations. It was difficult, because of the existing economic condition, to secure the eventual favorable action of the United States Congress on recommendation made through the Department of State by Kennelly and Fleming for participation.

The assurance of participation in Alaska by this action resulted in considerable cooperative activity with our Department of various governmental and other agencies which otherwise probably would not have been possible. Those interested include the Department of State, the Department of Commerce through the Coast and Geodetic Survey and the Bureau of



Standards, the Navy Department through the Naval Research Laboratory, the War Department through the Signal Corps, the Department of Agriculture through its Weather Bureau, the Carnegie Institution of Washington through our Department, the Alaska Agricultural College and School of Mines, and the American Telephone and Telegraph Company, as well as several individual contributions for special purposes.

The chief United States station thus established is that designated as the College-Fairbanks station, the terrestrial-magnetic, atmospheric-electric, earth-current, and auroral records and observations to be done at College and those in radio telegraphy and meteorology at Fairbanks, about 5.5 kilometers east-southeast of College.

With the cooperation of the International Polar Year Commission and the United States Weather Bureau, the Department has arranged also for continuous magnetic registrations and for auroral and meteorological observations at Point Barrow, Alaska.

Copies of the polar values in our world quadrangle compilations of magnetic data, as requested by the International Polar Year Commission in its Leningrad 1930 meeting, were communicated to the Central Geophysical Observatory of Leningrad for publication in its catalogue of magnetic determinations in polar regions.

## MAGNETISM AND ATOMIC PHYSICS

### EXPERIMENTAL

Tuве, Hafstad, Dahl, Loveridge, Patton, Brown and Seidenspinner continued the Department's experimental work in atomic and nuclear physics which has for its aim the study of some of the basic physical phenomena which underlie all macroscopic manifestations of magnetism and electricity. In particular, these efforts are directed toward studies of the simplest cases of the interaction at close distances of the known primary material particles—the electron and proton—which have both electric charge and magnetic moment.

*High-voltage work*—The efforts of the Department during the past six years to develop an artificial source of particles and radiations of sufficient energy to penetrate and disturb the tightly bound central nuclei of atoms of the various chemical elements had already reached the point by the spring of 1931 where beta-rays, gamma-rays and high-speed protons, having energy-equivalents of the order of a million volts and higher, had been produced (see pp. 290 to 295 of annual report for 1930–31). A fundamental technique for the direct artificial production of such requisite high-energy rays had thus been achieved, and except for limitations in intensity, due to the short duration of the high voltage produced by the spark-excited Tesla coil, this new tool was then ready for a large series of basic new investigations. The necessity for a voltage-source of greater steadiness and controllability than the Tesla coil had long been recognized and emphasized in reports and discussions. The virtue of the Tesla coil has been its simplicity and low cost as a source of potentials of one to several millions of volts for the development of high-voltage vacuum-tubes and technique. However, the cost of any new voltage-source of better type has necessitated a delay in making any improvements in this direction.

During this report-year efforts have been spent chiefly on the following items: (1) Tests of the inexpensive Van de Graaff electrostatic generator in air as a source of high voltages for this type of work, including its use for first tests of steady direct-current potentials of the order of one million volts on cascade-type vacuum-tubes, and the construction and test of a 2000-kilovolt generator, which is ready for use as soon as laboratory-space is available for its erection. (2) Attempts to make such observations as have appeared possible using the spark-excited Tesla coil without an unreasonable expenditure of effort and funds attempting to use this rather poorly adapted voltage-source, especially with a much simpler and more effective equipment in process of construction and test here in the same laboratory at the same time. (3) The construction of instruments and development of techniques for the observation and measurement of atomic and nuclear phenomena using these high-energy rays, including (4) the application of the older technique using radioactive sources to certain specific problems of outstanding importance for which we have purposely acquired unusual facilities, in particular a very large amount of radium-*D* in solution, for preparing strong polonium-sources.

The Van de Graaff electrostatic generator<sup>1</sup> in air appears from the Department's tests to be a nearly ideal voltage-source for these investigations, at least for voltages up to some millions of volts. A generator for use in the region 1000 to 2000 kilovolts, using a spun-aluminum sphere two meters in diameter, has been constructed and tested at the Department, and this equipment is ready for installation as soon as suitable housing with sufficient head-room may be arranged. The two-meter sphere, mounted on a 2-meter pedestal, easily reached potentials exceeding 2000 kilovolts above ground. One 6-inch belt was used at 6000 feet per minute, giving a charging current of 90 microamperes. Currents of 300 microamperes are available at this voltage if two 6-inch belts are used at 10,000 feet per minute as provided for in the machine, since leakage-currents are almost negligible below the limiting voltage. Violent fluctuations of voltage were produced in the outdoor-tests by flying bugs and lint, but tests during short intervals after cleaning the sphere indicated that a voltage-steadiness to within 3 per cent or even considerably better is to be expected with the generator installed in a suitably enclosed space.

Tests were made using this generator to apply direct-current potentials up to one million volts to the cascade-type vacuum-tubes as used for several years with the oil-immersed Tesla coil. Our tests showed definitely that no new or serious difficulties were to be encountered in the application of steady direct-current potentials.

Voltage-measurements for all of these tests with direct-current potentials were made by means of a generating voltmeter, as suggested by Van de Graaff and used independently by Kirkpatrick and by Gunn.

A highly satisfactory equipment for the production of high-energy particles, particularly of high-speed protons, is thus ready for use as soon as operating space becomes available. The Department's program has been designed and its equipment developed for investigations in the region

<sup>1</sup> R. J. Van de Graaff, Phys. Rev., vol. 38, 1919-A (1931).

between 1500 and 2000 kilovolts, at which voltages it could be said with certainty (even on the basis of classical computations) that the nucleus could be penetrated by protons and hence new information obtained. The unexpected and important achievement of Cockcroft and Walton in the Cavendish Laboratory, Cambridge, who recently demonstrated the artificial disintegration of lithium and other light nuclei by protons having speeds as low as 120 to 400 kilovolts, has prompted us, because of the impossibility to the present of providing an enclosed space for the 2000-kilovolt generator, to install in our present laboratory an auxiliary apparatus of similar design for voltages up to 600 or 700 kilovolts. This equipment is under construction.

The Tesla-coil equipment was used during the year for several experiments with high-speed protons, but its low intensity and uncontrollability as used with a "flashing" tube, emphasized the desirability of discontinuing efforts with this set-up and of utilizing the time and funds available on the new equipment, obviously so much better suited to ultimate serious work. If no other voltage-sources were available, our experiments have demonstrated that the Tesla coil certainly could be utilized for many or most of the experiments possible with other sources, but the modifications necessary for higher intensities and the complications introduced in the observations themselves by the varying output-voltage make it expedient to adopt one of several other methods for obtaining very high voltages.

Failing to observe any proton-tracks in a Wilson cloud-chamber at the grounded end when using a conventional Dempster-Ramsauer proton-source at the high-voltage end of a "dark" tube, because of the short duration of the high voltage produced by the Tesla coil, recourse was had again to a "flashing" tube (made to flash by unequal voltage-distribution) with magnetic analysis interposed between the tube and the Wilson cloud-chamber, in order to prevent high-speed electrons, soft X-rays, etc., from entering the latter and obliterating the proton-tracks. With this arrangement proton-tracks of the predicted range, corresponding approximately to the peak-voltage applied to the tube, were at once observable (December 8, 1931). Refinement of the slit-system in the magnetic analyzer made possible a first measurement of the range of 1000-kilovolt protons. Systematic observations with this apparatus were then begun on the effects of bombarding a thin aluminum-foil (separating the Wilson chamber from the high-voltage tube) by 1000-kilovolt protons. Efforts to improve the proton-intensity failed and further attempts seeking evidence of nuclear disintegration with this set-up were discontinued.

An experiment seeking independent qualitative verification of the hydrogen-isotope of mass two, announced in the autumn of 1931 by Urey, Brickwedde and Murphy, was also undertaken with a similar arrangement, but the evidence obtained must be regarded as incomplete until verified by using a more controllable set-up. Using magnetic analysis, ionized hydrogen-molecules (of mass two) are deflected to the same position as nuclei of the hydrogen-isotope of mass two of the same kinetic energy. The range of this nucleus should be just twice that of each of the two protons of the molecule. In a series of about 400 photographs, showing a total of about 5000 proton-tracks, a total of four or possibly five tracks of the predicted



range appeared. The quantitative relations are not significant, as the ratio of molecular to atomic ions of mass two depends on discharge-conditions. It should also be pointed out that similar considerations are important in connection with the ranges of the "natural  $H$ -rays" produced by collisions of alpha-particles with hydrogen-nuclei. It appears that this unknown possibility has not been of serious importance in any of the disintegration-observations reported in the literature, by reason of the very small proportion of the hydrogen-isotope of mass two.

Calculated tables have been prepared using Darwin's classical formulæ, giving the numbers, speeds and ranges of protons scattered by nuclei of various masses at different angles and for different initial velocities. Similar tables have been prepared for the hydrogen-isotope of mass two, and for several other possible and hypothetical bombarding particles.

A large proportion of the efforts during the past two or more years has been spent on instruments and techniques for the observation and measurement of atomic and nuclear phenomena, in order to be fully prepared to utilize fruitfully the high-voltage technique which has been developed as soon as a steadier voltage-source could be added to the equipment. The most fruitful methods of observation, because they are the most analytical, are those in which "single events" are separately observed, for example, the counting of separate high-speed protons or alpha-particles which have suffered deflection through a given angle by intimate collision with a relatively stationary atomic nucleus. Such techniques are particularly adaptable to the high-energy region, although the standard methods used so much in regions of lower energy—ionization-chambers, photographic density, and similar "averaging" techniques—are of course also useful. The technique of counters utilizing amplification by disruptive discharge, the Geiger point-counter, and particularly the Geiger-Müller tube-counter, have been studied in this Laboratory for the past several years, and new contributions to the technique have been made, particularly in connection with the powerfully analytical coincidence-methods so adaptable to this type of detector; measurements of counting-efficiency (by changing multiplicity of coincidences without changing solid angle), and similar studies were made (see previous annual reports).

During this report-year attention has been given chiefly to the Wilson cloud-chamber and to electrical methods which yield a knowledge of the ionizing power (ion-pairs per centimeter-path) of each particle as well as counting the particles. Improvements over the usual cloud-chamber technique have been made by increasing the mercury-spark light-intensity to permit the use of fine-grained positive emulsion, giving a considerable increase in the photographic resolution, and by a new mechanical design which is expected to have many advantages, avoiding leaks and giving simple and accurate control of the expansion-cycle. This apparatus is under construction.

In connection with the measurements of the extremely small ionization-currents or pulses produced by single high-speed particles, the Department has been interested in the possibilities of the recently announced FP-54 pliotron. A series of experiments made by Hafstad and Loveridge to determine the optimum operating conditions, essential precautions, and the ulti-



mate limitations gave the following result. Using a single tube mounted in vacuum, with lead cells at constant temperature, with grid floating at its equilibrium-potential, and with a galvanometer of  $1 \times 10^{-10}$ -ampere sensitivity and 5-second period, the limit of sensitivity for short-time events of unknown time-distribution is about 500 electrons.

This instrument has been utilized for the separate counting of protons and alpha-particles (by measuring their differing ionizations over the same short path) in much the same manner as Pose has used the Hoffmann duant-electrometer. The linear amplification-counter, using a multi-stage vacuum-tube amplifier, first developed by Greinacher and used so successfully in Lord Rutherford's laboratory during the past two years, has also been developed as a part of our instrumental technique.

Preparations have been under way for more than the past year, chiefly by obtaining the use of a large quantity of radium-*D* from discarded radon-tubes,<sup>1</sup> to undertake certain important experiments using the standard radioactive-source technique. The recent results obtained in several foreign laboratories using strong polonium-sources (from radium-*D*), leading to the epoch-making discovery of the neutron, announced by Chadwick, the only properties of which are mass and residual magnetic moment (or electric moment), show the important potentialities for the Department's work of this very unusual laboratory-asset. This radioactive work has been undertaken both by reason of the importance of the experiments themselves, and to insure against being misled in the interpretation of resulting data using the newer artificial-source (high-voltage tube) technique.

#### THEORETICAL

G. Breit of the faculty of the New York University continued as a research associate of the Institution. Publications noted later in this report were prepared by him at the New York University. He has continued his studies of the hyperfine structure of spectral lines due in part to the different position of spectral lines due to different isotopes of the same element. The displacements observed are much too large to be explained as the ordinary effect of the mass predicted by Bohr. He is investigating the possibility of explaining the shifts in terms of the size of the nucleus. It is found that the observed shifts are smaller than would be expected. Apparent contradiction of the arc- and spark-spectra of *Tl* has been explained by taking into account perturbations present between terms of the *Tl* spark-spectrum. *Hg* arc- and spark-spectra similarly fit in. The arc-spectrum of *Pb* is apparently more difficult to explain. However, a possibility due to changes in screening has been found. Also the order of magnitude of the expected shifts has been decreased by suitable modifications. The general conclusion is that isotope-shifts may be explained as due to changes in nuclear dimensions; the nuclear radius is supposed to be approximately proportional to the cube-root of the atomic weight; the distribution of positive charge within the nucleus is roughly uniform. The above theory is still tentative and more experimental data are needed for a satisfactory test.

<sup>1</sup> Acknowledgment is gratefully made to Dr. C. F. Burnam and Dr. F. West, of the Kelly Hospital, Baltimore, to Dr. G. Failla, of the Memorial Hospital, New York, and to Dr. J. L. Weatherwax, of the Philadelphia General Hospital, for the use of this material.

## EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY

The personnel of the Section of Experimental work in Terrestrial Electricity consisted of Gish (Chief of Section), Rooney, Sherman and temporary assistant-computers Roop and Nutting. Johnston, Wait and Torreson of the Section of Observatory Work also spent some time on investigations in terrestrial electricity.

*Preparations for Polar Year*—Extensive preparations for terrestrial-electric observations during the International Polar Year 1932-33 were made. Equipment was developed, or assembled and tested, for continuously recording the following elements at the proposed Polar Year station College, Alaska: (a) Air-potentials at two stations, one to serve as a standardizing station, the other located in an atmospheric-electric observatory-building so as to be more closely associated with the other atmospheric-electric elements; (b) both positive and negative conductivity, employing apparatuses similar to that developed for registering this element on the *Carnegie*; and (c) northward and eastward component of earth-current intensity for which apparatus was developed along the lines suggested to the International Polar Year Commission. Plans and provisions were also made for regular daily eye-observations of the density of small ions, of the density of Aitken nuclei, of visibility, and of the various meteorological elements which may be expected to produce local effects in the atmospheric-electric elements.

A program of special observations was developed with a view to more definitely determining whether auroral phenomena may have associated atmospheric-electric effects near the Earth's surface.

A duplicate of the equipment for registering earth-potentials at College, Alaska, was supplied to the Canadian Meteorological Service for its Polar Year station at Chesterfield Inlet. Detailed instructions were prepared for Department observers and others who requested information regarding the registration of earth-currents.

At the request of Dr. E. H. Colpitts, Assistant Vice-President of the American Telephone and Telegraph Company, Gish took part in a conference at New York City, July 7, 1931, to consider participation of that Company in the Polar Year program. It was agreed that (a) the cooperative arrangement for earth-current registrations at Tucson be continued to the end of the Polar Year; (b) the earth-current registrations begun by the Company several years ago be continued at least to the end of the Polar Year; and (c) two new stations, one at Houlton, Maine, and the other at Wyanet, Illinois, be equipped for earth-current registration during the Polar Year. Dr. G. C. Southworth, in charge of this work for the Company, feels this undertaking to obtain continuous earth-current registrations by employing telegraph lines will yield valuable data, even regarding the more difficult phase of the diurnal variation. The chief obstacle in these measurements on commercial systems has been an effect known technically as "noise" and other disturbances, which arise in part from electric-power systems. The method suggested by Gish for reducing these, by placing special electrodes at points as remote as feasible from regions where intense stray-currents from power-systems are likely to abound, was found effective.

*Atmospheric electricity*—Gish made a preliminary study of relations between changes in air-conductivity and air-potentials and found evidence that there may be at times of thunder-storm a sufficient net negative air-earth current to compensate the normal loss of negative charge from the Earth.

Sherman obtained continuous registrations of conductivity of both signs in a hut on the Department grounds, using apparatus being tested prior to its use at College, Alaska. The ratios of values obtained on the grounds to those obtained on the deck varied considerably during a day, but in no systematic manner; the mean values of these ratios for each day were, however, fairly consistent and only slightly less than those obtained from comparison between the standardizing station and the Deck-Observatory, namely, about 3.

*Earth-currents*—Preliminary studies of earth-current data from the Watheroo, Huancayo and Tucson observatories were made by Gish and Rooney. Rooney assembled data from the Watheroo and Ebro observatories comparing the character of diurnal variation on disturbed with that on quiet days for a five-year period. The difference found was similar to that disclosed in similar comparisons of magnetic data, thus disclosing a further interesting relation between the variations in earth-currents and those in terrestrial magnetism. Another interesting relation was revealed in a comparison between the electric and magnetic variations on some abnormal quiet days. Gish gave further thought to a possible explanation of the "anomalous" vertical earth-currents, which measurements in mountainous regions, in wells, and in mine-shafts are often interpreted as indicating. Measurements obtained by Forbush in a dry well at the Huancayo Magnetic Observatory during June to August 1931, indicating apparently diurnal and shorter-period variations in the registrations of "vertical" earth-current, offer a difficulty. It was thought possible that, because of heterogeneity in the conductivity of the structure about the well, a component of the horizontal earth-currents may be registered between the surface and bottom of the well. However, these data would seem more consistent with the view that a large part of the indicated vertical-current variations is part of a non-potential system, similar to that indicated by magnetic line-integrals.

*Earth-resistivity*—While no experimental work in earth-resistivity was done during the year, advice based on the Department's investigations was given others, chiefly those interested in the application of the method for practical purposes. Plans for exploring the crust of the Earth to depths of 50 miles or more by resistivity-measurements were further considered. Plans are being developed which may serve as a basis for consideration of a cooperative arrangement to realize this project—a project which should lead to information of fundamental importance, not alone for terrestrial magnetism and electricity, but also for aspects of geophysics and geology.

## FIELD-WORK AND REDUCTIONS

The field-work done and reductions made during the report-year are summarized below under (1) land magnetic survey, (2) observatory-work, and (3) reduction of oceanographical data of *Carnegie's* Cruise VII.



### LAND MAGNETIC SURVEY

In the Section of Land Magnetic Survey, Fisk (Chief of Section) has had the assistance of Wallis, Green, Davies, Hanson and Mansfield. The efforts of the Section have been directed primarily to the accumulation and discussion of magnetic data involving long-time changes.

The nature of the year-to-year changes in the values of the magnetic elements, usually spoken of collectively as "secular variation" is gradually becoming better known as the accumulation of data steadily though slowly increases and is subjected to analysis. Investigations in the light of this better knowledge have progressed to the point where it is generally recognized that it is desirable to approach the problem from a somewhat different standpoint from that hitherto adopted. Attempts to derive a satisfactory picture of the phenomenon by harmonic analysis have been disappointing, and the results of more abundant observations, with a more widely scattered distribution and covering a longer interval of time, are clearly indicating the reasons for this lack of earlier success. It now appears that superimposed upon a gradual change in the direction of the magnetic axis and the steady alteration in the magnetic moment of the Earth as a whole, which may be considered as the "true secular variation," there are other fluctuations of temporary character or having a shorter period, which should be evaluated and so far as possible eliminated before an analysis of the true secular variation can be profitably undertaken. It is well known, for example, that conditions associated with the cycle of solar activity indicated by the variations in the abundance of sunspots affect the annual mean value of the intensity-components derived from continuous values at observatories, and may also produce abnormal results when secular variation is obtained from single values at field-stations. Then there are other changes which have the appearance of being confined to restricted regions and which seem to run their course in a period of years; there is no present evidence that they are cyclical in character, or that the changes in one region are definitely connected with similar changes taking place in other remote regions. Obviously these changes should also be examined closely and their effect eliminated so far as possible before undertaking an analysis of the changes which presumably have their origin in causes affecting the entire Earth, and therefore constitute the true secular variation as assumed above.

Secular change for a given locality is most effectively determined from the continuous registrations obtained at that place by a standard magnetic observatory. The evaluation of the effect produced by the solar cycle can be fairly well determined for much of the Earth's surface from the present distribution of magnetic observatories, but that distribution is far from adequate to furnish the information necessary to outline the areas of regional activity. Only after there had been an accumulation of observations at widely scattered field-stations, an accumulation to which this Department had contributed very substantially, was it possible to make any approximate picture of what has been taking place over the Earth as a whole, or to obtain a comprehensive idea of this extremely important aspect of the problem. While the apparent changes in the annual rates of secular change clearly indicate that the regional activity is far from constant, the time over



which sufficiently accurate data have been gathered is much too short to state what the period may be through which the phenomenon runs its course. Efforts are being made in many countries to inaugurate or expand programs of periodic field-surveys from which the secular variation may be known in greater detail, and to all such efforts the Department has extended a sympathetic interest, and has given assistance where possible. The nature of the problem is such that substantial progress toward its solution demands that periodical observations be made at stations scattered over the whole surface of the Earth, and since in addition to the areas covered by the oceans there is much of the land-surface which is under jurisdictions wholly unable or at present indisposed to provide the means for work of this character, there still remains an urgent demand for the continuance of the work which this Department has carried on since its organization. Because of this inherent characteristic of the problem it can not well be approached by any agency or organization under governmental control of a single country whose activities are necessarily restricted by national boundaries, nor by investigators working only in laboratories, no matter how well equipped. For this reason the organization of the Department has been widely recognized as most fittingly adapted to carry on the work in the field and is regarded as a mobile agency for correlating and coordinating the otherwise detached operations by the different countries or within limited areas.

Realizing this responsibility, field-work in a few areas where it seemed especially urgent has been undertaken, though the extent of the work has been necessarily restricted because of the demands of other commitments. The entire western hemisphere south of Canada and the United States comprises an area, as has been shown by a discussion of the earlier results obtained by the Department, over which the rates of secular change are in general very large; and, so far as can be determined by the limited material available, those rates diminish rapidly with distance from recognized centers and are far from constant from year to year. Magnetic observatories are too widely scattered to provide adequate information regarding these changes, and a reoccupation of selected field-stations was considered of immediate importance. Two expeditions were accordingly sent out, one under J. W. Green who followed the South American coasts, visiting the more accessible portions and comparing standards with magnetic observatories, and the other under Earl Hanson who traversed the more difficult interior portions of Venezuela, Brazil and Peru. An opportunity was presented by the availability of the services of Frederick C. Brown, a former observer in the Department, to assist Dr. C. T. Kwei, of the Department of Physics, Central China College, to obtain desired experience in the technique of carrying out the program of field-observations, with the expectation that the Chinese national organizations may be able to undertake systematic magnetic observations within their own territories. The southern portion of the African continent is a region of exceptional secular changes, remote from any established observatory. It is, therefore, especially fortunate that the cooperation with the Department of Physics of the University of Cape Town could be continued. With the assistance of the Department, provision has been made for a permanent station there with the hope that

a set of magnetograph-instruments may eventually be installed. Such instruments will be in operation during the Polar Year, the absolute instruments having been supplied by us. The work planned by A. Walter, Director of the British East Africa Meteorological Service, was only partially completed because of adverse circumstances, and the arrangement has been continued. The plans for securing much desired magnetic data in the far north by means of observations on the ice at stations to be reached by the submarine *Nautilus* were not fully realized. A station was occupied in Spitzbergen, and one successful set of observations on moving ice was made.

#### FIELD-OPERATIONS AND COOPERATIVE SURVEYS

The accounts of the field-operations briefly outlined in the preceding paragraphs are given in more detail in the following section, so far as reports have been received from field-observers or cooperating institutions.

*Africa*—The cooperative work with the University of Cape Town which was begun in 1927 was interrupted during the past year while Dr. E. N. Grindley, under whose immediate charge the work was done, was on furlough from the University for study in England. The results of the observations made by Grindley were completely discussed by him under the title "The Earth's Magnetic Field in Southern Africa, Epoch July First, 1930" and presented as a thesis for a degree from his University.

In anticipation of renewing the work on Grindley's return from England, and of being able to carry out a series of observations repeated at short stated intervals at a fixed station conveniently located near the University, an observing-hut has been built with help of funds provided by the Department. The magnetometer-inductor C. I. W. No. 13 used in the field during the preceding three years had been returned for overhauling and restandardization, and magnetometer-inductor C. I. W. No. 17 was prepared to be sent out in its place.

In the cooperation with the Director of the British East Africa Meteorological Service, besides the C. I. W. stations at Nairobi and Zanzibar which were exactly reoccupied, the station at Abercorn at the foot of Lake Tanganyika, established by Beattie in 1909, was visited and reoccupied approximately. Two other stations available for future reoccupation were established.

*Asia*—Magnetometer-inductor C. I. W. No. 13 with accessory field-equipment was forwarded in August to Dr. S. L. Ting, Director of the National Research Institute of Physics at Shanghai, China, through whose kind offices the details of entry were arranged. On November 10, F. C. Brown, of the American Church Mission at Hankow, went to Shanghai to receive the instrument from Dr. Ting, and to make a comparison with the standards of the magnetic branch of the Zi-ka-wei Observatory situated at Lu-kia-pang. Conditions for beginning the contemplated series of observations at Hankow were unfavorable on account of the continuance of flood-conditions over much of that city as well as the unsettled political situation. However, Brown succeeded in assisting Kwei to become familiar with the operation of the equipment, and in February reoccupied the old station for secular variation. Brown and Kwei, during a brief vacation in April, were able to reoccupy the old C. I. W. station of 1907 at Changsha and to establish two other auxiliary observation-points in the vicinity. A more extended trip was arranged for the reoccupation of repeat-stations along the railway-

lines between Hankow and Peiping, and also of stations readily reached by the railway westward from the latter place.

*Australia*—No field-work for secular variation has been undertaken during the year. The routine control-observations have been maintained at the Watheroo Magnetic Observatory.

*Europe*—Soule had arrived in Bergen, Norway, May 8, 1931, to prepare for participation in the transarctic expedition of the *Nautilus* under the leadership of Sir Hubert Wilkins, as reported last year. During the time spent in waiting for the arrival of the *Nautilus*, which had been delayed by the necessity for repairs, comparison-observations had been made with the instruments of Professor Krogness at Hop and Dombaas in May and June and repeated in early July. The vessel finally left Bergen August 5, arrived at Tromsø August 9, and reached Longyear City, Advent Bay, Spitzbergen, August 15. Observations for inclination and intensity were made there August 17, declination observations being prevented by cloudiness. The *Nautilus* left Advent Bay August 18 and returned to that port September 8. A magnetic station was occupied on the ice at latitude  $81^{\circ} 40'$  north and longitude  $24^{\circ} 45'$  east, at which satisfactory determinations of inclination and intensity were secured though the rapid turning movement of the ice prevented the observations for declination. From Advent Bay, Soule returned by steamer direct to Bergen, and after further observations at Hop, September 19 and 20, he sailed from Bergen for New York October 3.

*North America*—Instrumental comparisons necessary for controlling the corrections of instruments used in the field have been carried out as usual in the Standardizing Magnetic Observatory in Washington. A new magnetometer-inductor No. 110 of the C. I. W. type, made for the Brazilian Government by the Precise Instrument Company, was completely standardized with the determination of all constants by Wallis with the assistance of Davies.

*West Indies*—Green and Hanson sailed from New York on August 4 for field-work in the West Indies and South America, taking as instrumental equipment magnetometer-inductor C. I. W. No. 26 and C. I. W. No. 16. After reoccupying former stations at Havana, Pinar del Rio, Matanzas and Santiago, in Cuba, they arrived at Kingston, Jamaica, August 30. The old station frequently reoccupied since 1905 will not longer be available and new stations in the vicinity of Kingston were established at Stony Hill and Wareka Station. Hanson reoccupied the station at Montego Bay. After comparisons of instruments with those at the San Juan Magnetic Observatory, San Juan, Puerto Rico, the two observers separated, Hanson's experience while associated with Green having been sufficient to enable him to proceed alone. Green continued work in the West Indies, observing at Port of Spain, Trinidad, and supporting stations, and at two stations in Barbados. At Trinidad, contacts which were established some years ago with the Office of the Crown Surveyor and which have been continued since that time with mutual pleasure and profit, were again renewed. That office has made very successful use of magnetic methods in its practical work and has often expressed its appreciation of the visits of observers of the Department who have found this interest very helpful. Hanson's contemplated work at Curaçao was necessarily omitted, and he began at once his work in South America, beginning at Caracas.

*South America*—Knowledge of secular change derived largely from the repeat-observations made by the Department during the past ten years



indicates that the entire continent, including the West Indies and the Caribbean Sea, is an area of especial interest. Because of the small number of magnetic observatories, the record of the rapidly shifting positions of the isopors (lines of equal annual change) can only be known from field-observations which should be repeated as frequently as each five years if possible, particularly near the foci for each element.

After completing the prescribed work in the West Indies, Green proceeded late in October to British Guiana, and occupied successively the station at Georgetown and its supporting station at Bartica, then Paramaribo in Dutch Guiana, and Cayenne in French Guiana. The problem of transportation from the last named point to Para in Brazil usually presents rather serious difficulties and involves the loss of considerable time, no regular line connecting the two places. Travel by aeroplane though available is usually not expedient because of the bulk and weight of the equipment to be transported. Green was fortunate in finding trading-vessels by which the journey was made without serious delay, and permitted the occupation of a station on the Oyapok on the Brazilian border. Para was reached November 23, and after formalities regarding the entering of the instruments had been completed he reoccupied the repeat-station at Pinheiro, first established by the Brazilian Magnetic Commission in 1904 and since repeatedly reoccupied by the observers of the Department, then made observations successively at the C. I. W. stations at Natal, Pernambuco and Bahia before reaching Rio de Janeiro January 3, 1932.

The visit at Rio de Janeiro was particularly profitable because of the opportunity afforded for conferences with the officials of the National Observatory, which operates the magnetic observatory at Vassouras and has made provision for an enlarged program of field-work by the purchase of two new magnetometers of the C.I.W. type, and also with the Director of the Meteorological Service and his assistants who were planning to establish two stations—one at Para and a second on an island of the South Atlantic—for cooperation in the Polar Year program. Green made a complete comparison with the standards at Vassouras, and, at the request of the officials who were not familiar with that type of apparatus, assisted in comparing with the observatory standard the new instruments just received.

After reoccupying the station at Colon, near Montevideo, Uruguay, Green reached Buenos Aires, Argentina, February 6. Relations between the Department and the Meteorological Office of Argentina have always been close with frequent cooperation. The plan, in which this Department had arranged to cooperate, of reoccupying during the present year all the magnetic stations established by the Meteorological Office about 20 years ago and comprising a network covering the entire country, was necessarily postponed. However, the immediate needs were met by making complete comparisons of standards with the standards of the magnetic observatories and with those at Pilar and La Quiaca, and by reoccupying stations at Mercedes near Buenos Aires, at Bahia Blanca in the south, and at Mendoza in the west. At Santiago, Chile, where he arrived March 24, Green found a growing interest in plans for attempting systematic magnetic observations, a new instrumental outfit having recently been secured. Owing to defects in the instrument, comparisons were made only in declination, in the expectation that when the instrument has been repaired a more complete comparison would later be made at Huancayo in order to determine the corrections on International Magnetic Standard. The stations at Santiago,



Valparaiso, Antofagasta, and Arica in Chile were reoccupied. Arriving at La Paz, Bolivia, April 26, the repeat-station at that place was reoccupied, and the opportunity was found for discussing the work with officials of the government and of educational institutions; no arrangements were made for establishing systematic observations, as no means were available for obtaining the necessary instruments.

Before proceeding to Huancayo, Green visited Arequipa, Peru, for making the usual observations and also to investigate further the region which was found on previous visits to be one in which the diurnal variation in inclination had a remarkably large range. During the observations of 1917, a year of sunspot-maximum, an extreme range of approximately 20' was found. Subsequent observations made in years nearer the period of minimum have given smaller ranges, usually of the order of 10'. After a comparison of instruments with those at Huancayo Magnetic Observatory, Green returned to Washington, occupying en route the stations at Old Panama, Corozal and Colon, Panama. His expedition was concluded with his arrival at Washington, June 21, and the final comparison of his magnetometer-inductor C.I.W. No. 26 with the standard instruments, magnetometer No. 3 and earth-inductor No. 48.

After reoccupying the stations at Caracas and Puerto Cabello in Venezuela, Hanson took the inland route to Maracaibo, where observations were made as well as at the auxiliary station on Isla Pajaro. On the return to Caracas a new station was established at Valera, the former station at La Ceiba being no longer suitable. This work was done between September 30 and November 3, when the overland journey to the upper Orinoco was undertaken. The traveling conditions from Villa de Cura to San Fernando de Apure were especially difficult on account of the condition of the roads at that very wet season. In order to make the necessary arrangements for the ascent of the Orinoco above San Fernando, he was obliged first to go down to Ciudad Bolivar. Leaving the latter place on December 6, he again ascended the Orinoco to Urbana and Puerto Ayacucho. Before entering Brazil across the Yavita portage to the Rio Negro, he obtained observations at Zamuro, San Fernando de Atabapo, Maroa, Comunidad and San Carlos, which were either close reoccupations of stations first occupied by Power in 1913, or were in the general vicinity, the alterations in the settlements in the meantime making better identification of the old positions impossible. The provisions for securing transportation and subsistence in this region were found very unfavorable on account of the depressed condition of the industries of the country, and progress was, therefore, slow and involved hardships which prevented a larger number of stations being occupied. Along the Rio Negro route to Manaos, observations were made at Cucuhy, San Gabriel, Santa Isabel and Barcellos. The central situation of Manaos on the river-systems tributary to the Amazon, made that a convenient place from which to make shorter trips to Boa Vista, near the Guiana border on the Rio Branco; to Santarem and Obidos on the lower Amazon, the station at Pinheiro at its mouth having been already occupied by Green; to the upper Madeira and the Mamore Rivers on which trip reoccupations were made at Porto Velho, Abuna, and Guajara Mirim in Brazil, and Guayaramerim, Riberalta, and Cachuela Esperanza in Bolivia—the last being a new station chosen particularly for its favorable location at the portage for a permanent repeat-station. This last trip occupied the month of June and on its completion Hanson returned to Manaos and left early in July by Steamer for Iquitos, Peru.

## SECULAR VARIATION AT SEA-STATIONS FROM GALILEE AND CARNEGIE OBSERVATIONS

The tracks of the various cruises of the magnetic-survey vessels of the Department, the *Galilee* and the *Carnegie*, were chosen so as to intersect as frequently as practicable and to distribute those intersections as widely over the oceans as sailing conditions and the distribution of the ports of call permitted. Preliminary values of secular variation have been worked out, first by Ault and later by Johnston, by means of the chart-differences which were kept current during the progress of the cruises as a part of the routine of the voyages. The method of grouping the observed results indiscriminately, however, made no use of such refinements as might be introduced by a limited use of the least-square principle, or by taking into account the non-linear character of the variation in secular rates over the considerable areas included within the groups. The importance of getting the best possible values of secular change during the period of the cruises, that is, from 1905 to 1929, fully warrants a thorough discussion of the results accumulated in that period. The preliminary results already published have been valuable for the preparation of navigational charts, but they vary among themselves too much to be useful in the study of the isoporic movements or shift of the lines of equal annual change of any of the elements. The labor involved in the analysis of so much material by any process involving the use of least-square computations is obviously very great, so that only a beginning has been thus far made. However, preliminary tests of many methods of dealing with the material have been applied and a method selected and tried with promising results.

The conditions are such that certain arbitrary assumptions are necessary, but experience shows that the assumptions may reasonably be granted. It may be assumed that recent isomagnetic charts such as those of the United States Hydrographic Office for 1925, adopted as most suitable for the epoch of the cruises of both vessels, are approximately correct. This is justified by the consistency of the chart-differences found by comparing actual observations with scaled values from the chart. It is, therefore, safe to assume that the rate of change of the element with small changes of latitude or longitude, such as would be necessary to refer an observed value from the place of observation to a nearby point on a line passed smoothly through a group of stations, may be taken from the chart without danger of appreciable error. It is also convenient to consider small portions of the Earth's surface, for example, a quadrilateral measuring  $20^\circ$  of latitude by  $20^\circ$  of longitude, as a plane surface and the geographical coordinates as rectangular coordinates; any error due to this assumption will be practically absorbed in the second-degree coefficients of the derived equations.

The general method which has been found to give the best results may be explained best by an illustration. The paths of *Carnegie* Cruise II and Cruise V are found to intersect near  $27^\circ 9'$  south latitude and  $275^\circ 4'$  east longitude. Six declination-stations of the former and eleven of the latter lie near enough to this point of intersection to be safely utilized. A line joining the stations of either cruise would be somewhat irregular, but a smooth line may be arbitrarily drawn through them so that the displacement of the observed position from an adjacent point on the line either in

latitude or longitude, as is most convenient, would be small, seldom as much as one degree, and usually only a few tenths of a degree. For such small distances the gradient or change of declination per degree may be quite safely taken from the chart, and the observed value of declination converted to a corresponding value on the line. By taking carefully scaled values of declination from the chart, we found that the chart-declination along the smooth line through the stations on the track of Cruise II were well represented by the equation  $D_{ch} = 15^{\circ}35' + 0.035 \Delta\phi - 0.0315 \Delta\phi^2$ . The computations are greatly simplified if it is assumed that the coefficient of the second-degree term thus derived for the secondary change of chart-values may be also used in a similar equation, applicable to the observed values which may refer to a different epoch. Such an assumption has been made and the resulting equation for the observed values becomes  $D_{CH} = 16^{\circ}22' - 0.037 \Delta\phi - 0.0315 \Delta\phi^2$ : from these two it follows that  $D_{CH} - D_{ch} = 0^{\circ}87' - 0.072 \Delta\phi$ . In a similar way, it may be shown that for the group of stations on the track of Cruise V the difference between the chart-values and the observed values in that vicinity is expressed by  $D_{CV} - D_{ch} = 0^{\circ}26' + 0.005 \Delta\phi'$ . Finally by evaluating  $\Delta\phi$  and  $\Delta\phi'$  for the latitude of the point where the two cruises intersect, that is, for  $-27^{\circ}9'$  (south latitude negative), the change in the 5.1 years between the dates of the two passages becomes  $(D_V - D_{II}) = -22'.6$  or  $-4'.4$  annually.

By a judicious selection of the arrangement of stations and lines, the foregoing computations may be made with fair rapidity. A general idea may be also gained as to the reliability of the individual observations and in certain cases observations which do not conform sufficiently to the trend indicated by the others may be rejected according to any recognized criterion. The assumption of substantial accuracy of the charts implies that the pattern of the isomagnetic lines is practically correct and, therefore, that the coefficient of  $\Delta\phi$  in the expression for the difference between the chart and observed values should be relatively small. A large coefficient indicating that the difference between chart and observation varies rapidly with a change in latitude (or longitude as the case may be) is evidence of erroneous values near the end of the line and these should be examined before the resulting annual changes are adopted. In general, the reductions already completed have resulted in secular-change values much more consistent than were derived from the means indiscriminately taken in the preliminary compilations.

#### ISOPORIC CHANGES IN THE CARIBBEAN AND ADJACENT LAND-AREAS

Among the earliest expeditions sent out by the Department, in its initial land magnetic survey, were those to the lands bordering on the Caribbean Sea. The expeditions of Green and Hanson during the past year have retraced much of this same territory, which has also been visited in its various parts at intervals during the intervening years. From preliminary studies of the secular variations derived from the results obtained on these expeditions, it is known that the annual changes in all the magnetic elements are exceptionally great in this general region, and furthermore that these rates are undergoing relatively rapid alterations. When lines of equal annual



change for any element (the isoporic lines) are drawn, they therefore present complicated patterns. It is a matter of very great interest to discover if possible how these patterns may alter their forms or shift their positions in the course of years. If there were a sufficiently dense distribution of magnetic observatories from which continuous records of change were available, the problem would be much simplified. In the absence of such records, an attempt has been made by Mansfield to derive an answer to the question by a discussion of the results obtained in the field even though they are irregularly distributed over the area and throughout the interval. When this discussion is completed it is hoped that isoporic charts for each of the elements may be drawn for the three epochs, 1910, 1920 and 1930. The results so far obtained appear to corroborate the conclusions provisionally stated that the isopors of declination forming an oval in eastern Brazil, the isopors of inclination forming a similar pattern in Ecuador, and the horizontal-intensity isopors surrounding the West Indies, are all contracting toward their respective centers at the present time. It is hoped that an extension of this investigation will show something of the character of these contractions and possibly of their interrelations.

#### OBSERVATORY-WORK

The Section of Observatory-Work has continued with Johnston as Chief of Section; he had the assistance of McNish, Miss Balsam, Miss Miller, and Scott, and occasionally of Torreson and Wait. The members of the staff engaged at the observatories are mentioned in the reports of the observers-in-charge.

The year has seen the installations of instruments for the extensions of the Department's observatory-programs indicated in last year's report, namely, the spectrohelioscopes supplied by the Mount Wilson Observatory at Watheroo and Huancayo, and horizontal- and vertical-component sesimographs in cooperation with the Institution's Advisory Committee in Seismology at Huancayo. After test in California, the Benioff vertical-component seismometer was shipped directly to Peru. The two Wenner horizontal-component seismometers were forwarded after determination of their constants at Washington in cooperation with the Coast and Geodetic Survey.

The three inductometers, for making high-speed records of minute changes in magnetic vertical-intensity, after the design of A. Crichton Mitchell, referred to in last year's report, were received. One was shipped to Watheroo for installation. A second inductometer was sent to College, Alaska, where it will form part of the equipment for the International Polar Year station.

In order to investigate the variations of the ionized regions (Kennelly-Heaviside layer) of the upper atmosphere, so important a factor in terrestrial magnetism and electricity, a radio laboratory and equipment were designed for the Huancayo Magnetic Observatory. Part of the special equipment has already gone forward and the remainder is now in construction at Washington.

In view of the great importance to research in terrestrial magnetism and electricity of data from polar regions, extensive preparation was made by the Department in anticipation of participation in the International Polar Year program of 1932-33. In cooperation with the International Polar



Year Commission, the observatories at Watheroo and Huancayo are being supplied with the Commission's specially designed magnetograph for high-speed records. Instructions for the installation and operation of these were prepared. C. J. McGregor, of the Weather Bureau, who will be in charge at Point Barrow, was trained in the installation and operation of the insensitive magnetograph (supplied by the International Polar Year Commission) and the necessary absolute instruments (supplied by the Department) for control of the magnetograph.

The important College-Fairbanks Polar Year station in Alaska, for the United States, was realized through the cooperation of the Department with the Coast and Geodetic Survey, the Naval Research Laboratory, the Signal Corps, the Alaska Agricultural College and School of Mines, and the International Polar Year Commission. A complete program of magnetic, atmospheric-electric, earth-current, auroral and Kennelly-Heaviside layer observations has been arranged. As a result this will be one of the principal stations of the Polar Year program. The necessary buildings to house the equipment at both the College-Fairbanks and Point Barrow stations were designed in the Department.

Three sets of the special la Cour magnetographs were purchased for use at the College-Fairbanks station. These magnetographs were tested at the Cheltenham Magnetic Observatory of the Coast and Geodetic Survey and necessary constants were prepared by Johnston, McNish, and McComb—the last named of the Coast and Geodetic Survey.

#### OBSERVATORY-OPERATIONS

The details of operation at the magnetic and electric observatories of the Department and at those observatories with which the Department has cooperated during the report-year are briefly summarized below.

*Watheroo Magnetic Observatory, Western Australia*—The Watheroo Magnetic Observatory is situated in latitude  $30^{\circ} 19' 1''$  south and longitude  $115^{\circ} 52' 6''$  east of Greenwich, 244 meters (800 feet) above sea-level.

The preliminary mean values of the magnetic elements for all days of the year 1931 as deduced from the magnetograms, referring the elements to the north-seeking end of needle and reckoning east declination and north inclination as positive, are: Declination  $-4^{\circ} 03' 2''$ ; horizontal intensity 0.24646 C. G. S. unit; vertical intensity  $-0.51215$  C. G. S. unit; and inclination  $-64^{\circ} 18' 0''$ . The preliminary values of the annual changes in the magnetic elements for the period 1930.5 to 1931.5 are  $+4.8$  in declination,  $+12$  gammas in horizontal intensity,  $-41$  gammas in vertical intensity, and  $-0.3$  in inclination.

Earth-potentials, over the system described in previous reports, were continuously recorded.

Continuous records of air-potentials were obtained with the standard potential-gradient apparatus. Standardization-observations were made at approximately monthly intervals as before. The mean of the series for 1931 gives a reduction-factor of 1.12 as compared with the mean value of 1.11 of the previous year. The preliminary mean value of the potential gradient for the year 1931 is 78.0 volts per meter. This value excludes the months of February and March during which the smoke from bush-fires vitiated the registrations. A field potential-gradient recorder was operated

at the top of a specially constructed tower on the Observatory-site, 25 feet above ground-level, from June 1931 to March 1932, and the results from this station show closely similar diurnal-variation characteristics, both during the winter and summer months, to those obtained with the standard recorder. Using the same field-equipment a series of 15 complete zero-day traces was obtained during May 1932, at a station near Moora, about 24 miles south of the Observatory; similar work at Perth, 100 miles south of the Observatory, is in progress. The underground concrete recording-chamber constructed during the previous report-year unfortunately developed leaks during the rainy season and has thus, so far, not been used. However, at the appropriate time the necessary waterproofing was accomplished and installation of the recording apparatus is now in hand.

Positive and negative air-conductivities were recorded as during previous years. The weekly calibrations and tests were made. As usual, during the months of February and March the records were seriously affected by the smoke from bush-fires. The preliminary mean value of the positive air-conductivity for the year 1931, excluding February and March, is  $1.91 \times 10^{-4}$  E. S. U. and for the negative air-conductivity  $1.76 \times 10^{-4}$  E. S. U.

The directional recorder of atmospherics on loan from the Australian Radio Research Board of the Council for Scientific and Industrial Research was returned to the Observatory after having undergone structural modification. Pressure of more urgent work prevented the completion of the installation of the apparatus in the report-year, but it is expected that the recorder will be again in operation during the latter part of 1932.

A spectrohelioscope designed by Hale and donated by the Mount Wilson Solar Observatory was received and installed in a specially constructed building. Systematic observation with this instrument has not yet been begun pending the finalization of an international scheme of observation and report.

The horizontal loop, enclosing an area of 180 acres, for use with the Mitchell vertical-intensity recorder was mounted on the boundary-fence around the Observatory-grounds.

The radio installation was inspected by the Assistant Radio Inspector for Western Australia on March 4, 1932, and, subject to certain Commonwealth regulations being complied with, our request for license to use higher transmitting-power was granted. Specifications for the construction of a transmitter to fulfil these requirements were prepared and approved by the Radio Inspector. The usual radio schedules were maintained and official messages were regularly transmitted and received.

The usual meteorological observations were made daily and the self-recording meteorological instruments were kept in continuous operation. Meteorological data were supplied, as heretofore, to the Australian Commonwealth Weather Bureau.

All computations and reductions were maintained current. Various memoranda on instrumental equipment and procedure were prepared by members of the staff. The Institution was represented at the Conference of Physicists, Mathematicians and Astronomers, in Sydney, August 1931, by Wood, who presented a paper prepared by Parkinson on "The Diurnal Variation of Potential Gradient." Wood also reported to the Conference on the Observatory's program in radio and atmospherics.

Parkinson acted as observer-in-charge throughout the year. Observer Wood continued as chief assistant. Curedale acted as junior observer and radio operator. Crowne, junior observer, resigned at the end of 1931, being

replaced by Culmsee from January 1, 1932. Caswell continued as electrician and mechanic throughout the year. The increased amount of routine and observational work, new installation and improvements to existing equipment which have been accomplished during the present report-year have been possible only by the zealous application of all of the assisting staff.

The Commonwealth Government, through its Department of Customs, has continued to extend to the Observatory all possible assistance in the matter of the entry of equipment and supplies. Professor Ross of the University of Western Australia continued his lively interest in the Observatory and its work, and recognition is due for the assistance he has rendered from time to time.

*Huancayo Magnetic Observatory, Peru*—The Huancayo Magnetic Observatory is situated in latitude  $12^{\circ} 02'7$  south and longitude  $75^{\circ} 20'4$  west of Greenwich, in the central valley of the Peruvian Cordillera at an altitude of 3350 meters (11,000 feet) above sea-level. Huancayo, the terminus of the Ferrocarril Central del Perú, is 15 kilometers distant by road from the Observatory.

The preliminary values based on the magnetograms for all days during the year 1931 are as follows, reference being to the north-seeking end of the needle, east declination and north inclination being reckoned positive:  $+7^{\circ} 30'8$  in declination; 0.29622 C. G. S. unit in horizontal intensity;  $+0.00951$  C. G. S. unit in vertical intensity;  $+1^{\circ} 50'3$  in inclination. The preliminary values of vertical intensity and inclination for all days as deduced from the magnetograms are  $+0.00813$  C. G. S. unit and  $+1^{\circ} 34'3$  for 1929, and  $+0.00885$  C. G. S. unit and  $+1^{\circ} 42'7$  for 1930. The preliminary values of the annual changes for the period 1930.5 to 1931.5 are  $-5'8$  in declination,  $+9$  gammas in horizontal intensity,  $+66$  gammas in vertical intensity and  $+7'6$  in inclination.

The number of zero-days in potential gradient, that is, those days on which no negative potential was recorded, varies greatly from the wet to the dry season. During the dry season of 1931 from May to October there were available 24 zero-days which gave an average value of the potential gradient of 47 volts per meter. For these 24 days the average value of the positive conductivity was  $4.4 \times 10^{-4}$  E. S. U. and for the negative conductivity  $4.3 \times 10^{-4}$  E. S. U. During the wet season of the year there were available for averaging only eleven zero-days. The mean value of potential gradient obtained on these days was 38 volts per meter, for the positive conductivity  $5.7 \times 10^{-4}$  E. S. U., and for the negative conductivity  $5.3 \times 10^{-4}$  E. S. U.

The preliminary mean value of the potential gradient at the Observatory for the calendar year 1931 was 44 volts per meter, as based on the zero-days for the year. The mean value of the reduction-factor determined in 1931 was 1.08, the same as the mean for the years 1927 to 1930.

The preliminary mean value of the positive conductivity was  $4.8 \times 10^{-4}$  E. S. U. for 1931, and the corresponding mean value of the negative conductivity was  $4.6 \times 10^{-4}$ .

Beginning in July 1931 and lasting well into 1932, a heavy program of new building-construction at the Observatory was completed. This involved the erection of a seismograph building, a spectrohelioscope building, and a radio building combined with auxiliary quarters. The seismograph building is of double-wall reinforced-concrete construction and the other two buildings are of brick. All have framed roof-structures covered with roofing felt and native tile.



The Benioff vertical-component seismometer and recorder were received and installed. The Wenner horizontal-component seismometers and recorder were en route from Callao at the end of the report-year.

The spectrohelioscope has been set up for some months, but partly on account of bad observing weather final adjustment has been somewhat delayed.

The radio power-unit and transmitter were installed and put in regular operation. The former, consisting of a Ford model A motor connected to a 9-kilowatt, 3-phase, 220-volt, 60-cycle generator and a secondary motor-generator unit for charging the 110-volt battery, supplies all the power for the radio transmitter, for the radio receivers, and a smaller battery-powered transmitter, as well as light for the building.

Ledig has remained in charge of the work of the Observatory during the entire year. Seaton continued oversight of the construction-work, completed the radio installation, and operated the radio instruments. Forbush sailed from Callao on August 13, returning to the Department in Washington. Cairns and Mrs. Cairns arrived August 11, 1931, in Callao from Washington. Cairns replaced Forbush, and Mrs. Cairns has been giving much needed assistance in the work of the Observatory-office. M. T. Quintana and T. Astete continued as clerical assistants in the office.

The Observatory has continued to enjoy the helpful friendship of the officials of the Peruvian Government and of the local residents. The staff has reciprocated in every way, with the result that the general good feeling toward the Observatory is maintained. The fact that our radio station has been given a free license for an unlimited period speaks well for the confidence in which the Observatory is held and for the real regard of the Government in scientific endeavor. The continued assistance of the United States Embassy in obtaining free entry for shipments of materials and equipment for the Observatory is acknowledged appreciatively, as well as the kindness of the Peruvian Government which has continued to allow us this courtesy.

*Washington, United States*—The registration of air-potentials and of air-conductivity (positive and negative alternately by weeks) and the required controls were continued, but the registrations were not reduced except when required in connection with special investigations such as the registration of large ions by Wait and Torreson, and for comparison with the records of the two air-conductivity recorders tested by Sherman before sending them to College, Alaska, to carry out registrations there during the International Polar Year. The potential-gradient registrations were satisfactory 97 per cent of the time, and those of conductivity 85 per cent. During the calendar year 1931, 212 days were without any negative air-potentials. Observations for determining the factor to reduce the registered air-potentials to volts per meter over a level area were made on eight occasions during the year by Sherman, Roop and Nutting, a total of 1530 observations at one-minute intervals being made. The tentative value of the factor for the calendar year 1931 is 1.25, the same as for the previous year. In pursuance of a policy outlined in the report for the previous year, observations of air-conductivity were made at the standardizing station on nine occasions during the calendar year 1931. The mean ratio of the conductivity measured at the field-station to the value registered simultaneously at the Deck-Observatory was for positive conductivity 2.7, and for negative it was 3.0. This difference of 0.3 is probably of no significance.

In addition to the air-potential registrations on the deck, records were obtained with a Benndorf recorder with an exposure from a window on the



southwest side of the first floor of the main Laboratory. These continued throughout the report-year. Some reductions from these were compared with values obtained from simultaneous registrations on the deck. The only unexpected feature found was a definite difference in the character of the diurnal variation. The reason for this has not yet been definitely established.

#### COOPERATION WITH OTHER OBSERVATORIES

*Apia Observatory, Western Samoa*—Active cooperation with Apia Observatory in the South Pacific Ocean (latitude  $13^{\circ} 48'$  south, longitude  $171^{\circ} 46'$  west) continued during the twelve months covered by this report. This cooperation, begun in 1921, has been concerned fundamentally with the maintenance of a program of work in atmospheric electricity, although the Department is also interested in the progress of research and observation in terrestrial magnetism as well as other geophysical subjects. In addition to advice concerning instruments and methods of work the Department has also given a grant in aid to defray the expenses of maintaining two self-recording electrometers for measuring atmospheric-electric potential. With the assistance of the Department and its favorable recommendation, the Rockefeller Foundation has provided a substantial grant for 1931 and 1932 toward the expenses of the Apia Observatory and the Christchurch Observatory, New Zealand, to insure the continuance of these stations without the interruption which might otherwise have resulted from the serious economic conditions prevailing in New Zealand.

K. C. Sanderson concluded his engagement with the Apia Observatory at the end of December 1931, after four years' service in Samoa. His place was taken by H. B. Sapsford, who was seconded from the Public Works Department in Wellington and who reported for duty at the Observatory on November 27, 1931. There was accordingly an overlap of duties of approximately one month and the continuity of the observations was not disturbed.

The variometers for recording horizontal intensity and declination were maintained in operation and were controlled approximately once a week by absolute observations with the Tesdorpf magnetometer and Schulze earth-inductor. The vertical variometer was unfortunately out of action. A renewed attempt to operate this instrument was made in June 1932.

The Public Works Department erected a small hut for the spectrohelioscope which the Observatory received on loan some time ago from Mount Wilson Observatory.

The program of work in atmospheric electricity was the same as last year, namely, continuous records of the gradient of potential at two stations. One of these, the "Land Station," is located in the grounds of the Observatory, and the other, the "Lagoon Station," is a small hut about one kilom-

*Preliminary monthly means of potential gradient in volts per meter at Apia, Western Samoa, 1930 and 1931*

Station	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Land . . .	1930	.....	104	94	88	93	84	80	107	122	120	97	93	98
	1931	89	79	98	98	111	108	114	104	117	103	113	117	104
Lagoon..	1930	142	88	94	97	92	104	111	113	136	93	91	129	108
	1931	129	95	108	119	123	129	144	116	141	121	128	133	124

eter distant, erected over the shallow waters inside the coral-reef. The instruments employed are Benndorf electrometers fitted with ionium-collectors supplied by the Department. The preliminary mean monthly values of potential gradient in volts per meter for days without negative potential based on reduction-factors 1.00 and 0.63 for the Land Station and the Lagoon Station, respectively, are given in the preceding table.

The program in meteorology followed since the founding of the Observatory was continued. The means for the various elements derived from continuous records (except humidity) during 1931 are given in the following table:

*Meteorological summary, Apia Observatory, Western Samoa, 1931*

Month	Pressure	Temp.	Rainfall	Rel. hum. (9 a.m.)	Sunshine	Wind- velocity
1931	inches	°F.	inches	per cent	hours	miles/hr.
Jan.....	29.709	80.2	17.20	84	159.8	5.4
Feb.....	29.689	80.1	19.97	83	126.9	3.2
Mar.....	29.823	80.4	10.47	81	164.5	3.6
Apr.....	29.823	79.7	15.94	78	205.4	4.6
May.....	29.858	79.3	13.90	81	161.3	4.4
June.....	29.882	78.1	10.87	79	195.7	4.9
July.....	29.898	78.4	3.90	74	259.2	5.6
Aug.....	29.862	78.8	2.00	77	219.1	5.3
Sept.....	29.882	79.0	5.48	77	216.2	4.5
Oct.....	29.851	78.6	8.34	74	227.7	3.4
Nov.....	29.795	79.0	5.82	74	234.6	3.5
Dec.....	29.793	78.6	8.98	76	177.0	2.9
Year.....	29.822	79.2	122.87	78	2347.4	4.3

*Tucson, United States*—Registrations of air-potential and of positive and negative air-conductivity, the necessary controls, scaling and part of the reduction were made throughout the year by Observer-in-Charge Ludy and Observer Hershberger of the United States Coast and Geodetic Survey, cooperating with the Department. The final compilations at the Department were practically completed to the end of 1931. The numbers of complete daily records (in which no more than three successive hourly means and a total not to exceed four hourly means are missing) are: Potential gradient, 254; positive and negative conductivity, each 348. The smaller number of complete records for potential gradient is due to the frequency of pronounced disturbances in the electric field. There were 127 days on which no negative potential was recorded. The mean value of potential gradient for the year 1931 is 48.1, that of positive conductivity is  $2.20 \times 10^{-4}$  E. S. U., and that of negative conductivity is  $2.11 \times 10^{-4}$  E. S. U. The mean reduction-factor determined from 1560 measurements at the field-station obtained on eight days was 1.23; departures from this of the mean values for individual days were relatively small.

Under the cooperative arrangement with the Mountain States Telephone and Telegraph Company mentioned in the report for last year, earth-current registration has been continued without important interruption.

*College, Alaska*—Cooperation with the auroral observatory at College, Alaska, Professor Veryl R. Fuller, of the Department of

Physics of the Alaska Agricultural College and School of Mines, being in charge. The report by Professor Fuller on his compilations and discussions of the parallaxic data obtained during the season of 1930-31 was edited and prepared for publication at Washington. It appeared in December 1931 and March 1932 issues of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. During the season 1931-32 a goodly number of parallaxic photographs was taken. About the middle of January 1932, the weather conditions became such, with heavy snow-storms and winds, that the road was completely blocked to station No. 2, thus causing an interruption until late in February in the series of simultaneous photographs at the two stations. During February the displays were perhaps better than any during previous months, partly because the auroræ were themselves somewhat better and partly due to the absence of cloudiness. Quite a large number of excellent parallaxic photographs of unusually fine displays was obtained during March 1932. Measurements of photographs by Professor Fuller are in progress, as also the preparation of a discussion of the resulting data.

#### REDUCTION AND DISCUSSIONS OF OBSERVATORY-DATA

Johnston, McNish and Miss Balsam have continued the reductions of the Watheroo and Huancayo magnetic data. Authorization was given by the Institution to its Division of Publications for publication of the completed manuscript on the Watheroo magnetic results for 1919-30. The Huancayo results in declination from 1922 to 1927 and in all elements for 1928 to 1930 were reduced and tabulations of these were prepared for publication.

An analysis of the diurnal variations at Watheroo shows the regular seasonal changes which might be expected by the transition of an upper-air current-system—originally suggested by Balfour Stewart—moving with the seasonal change in the upper layers of the atmosphere. On the other hand, there is a very great range in the diurnal variation of the horizontal component at Huancayo, which in the case of the north-component has a range of over 160 gammas for the months of March, April, September and October in the years 1929 and 1930. This is approximately three times that obtained employing the constants resulting from Chapman's analysis published in 1919 of the data from nineteen observatories for the year 1905. McNish has advanced two possible explanations of the discrepancy, which are substantiated by data from other observatories in the surrounding region and by the occasional series of diurnal-variation observations obtained at field-stations by Department observers. The first assumes that the apparent anomalous large diurnal-variations may arise from a denser current-flow owing to a lower resistance of the upper atmosphere while passing over Huancayo, but this factor would contribute only in a small degree. The second assumes a denser current-flow over the western hemisphere, with a crowding of the lines of flow over northern South America, as is to be expected because of the southward displacement of the magnetic equator in the western hemisphere. Thus this apparent anomaly would be quite consistent with the hypothesis that diurnal variations are produced by induced currents in the upper atmosphere. On the other hand, if diurnal variations were due to diamagnetic effects, as suggested by Gunn, the observed north-component at Huancayo should ex-



ceed that computed from Chapman's coefficients by a factor of less than four-thirds, instead of three as is observed. In support of this second assumption may be mentioned the large residuals over the computed ranges from Chapman's constants presented by other observatories near the meridian  $75^{\circ}$  west of Greenwich. Thus the data from the Cheltenham and Vieques observatories, in latitudes  $39^{\circ}$  and  $18^{\circ}$  north, respectively, show variations in the north-component typical of latitudes  $60^{\circ}$  and  $35^{\circ}$ , respectively.

Computations of solar and lunar magnetic variations at Watheroo, 1919-30, according to the scheme indicated on pages 285 and 331 of the annual report for 1930-31, were begun by Bartels with the help of Miss Assmann of Berlin and are nearing completion.

The harmonic analyses of the variability of the quiet-day diurnal magnetic variations at Watheroo (see page 330 of 1930-31 report) were completed by Bartels with the help of Kolar, Scott and Duvall. The discussion of this voluminous material is under way.

Wait and Torreson continued reduction of the Watheroo Observatory atmospheric-conductivity records for publication. It was early recognized that it would be desirable to determine the extent to which temperature-changes of the apparatus might affect the records (see pages 273 and 305 of annual reports for 1928-29 and for 1929-30). Temperatures during 1922-30 were tabulated and final temperature-coefficients for each of the two units (positive and negative) were determined by least-square adjustments for 1924-29. No values could be determined for 1930 owing to frequent readjustments, while for 1922-23 sufficient control-observations were not available during the experimental stages of installation and adjustment. The temperature-coefficients for some unknown reason were larger in the earlier than in the later years of record. Because the temperature-ranges in the Observatory from year to year are so similar, it was decided to make corrections because of temperature-changes only when they would affect resulting values by more than several per cent. The compilations of scale-values for 1922-30 were revised, graphs were prepared, and tables for converting scalings into absolute measure were completed.

Further analysis of atmospheric-electric data from the Deck-Observatory in Washington was made by Gish and Sherman.

Preparation of manuscript of compilation and some discussions of the earth-current data from the Watheroo, Huancayo and Tucson observatories was continued by Rooney. This first detailed manuscript is nearing completion.

Wallis and Davies continued the reduction of the magnetic records obtained by the Byrd Antarctic Expedition during May 1929 to February 1930. The magnetograms were read and hourly values of the three elements were tabulated and checked. The three scale-values were computed as well as base-line values for declination and horizontal intensity and temperature-coefficient for horizontal intensity, and thus the final hourly values for these two elements in absolute value are completed. The tabulations for hourly values of vertical intensity are awaiting compilations to determine the temperature-coefficient of the variometer.



## OCEANOGRAPHIC REDUCTIONS

The reductions of the large quantity of oceanographic data—physical, chemical and biological—gathered on the last cruise of the *Carnegie* in addition to those in terrestrial magnetism and atmospheric electricity, and their preparation for publication, were continued under the general supervision of the Acting Director. Sverdrup, research associate at Bergen, assisted by Soule, Graham, Scott, Miss Clarke, and Miss Ennis of the temporary staff, and Ennis and Forbush of the regular staff, took part in these reductions. Others engaged for short periods on special features of the discussions were: Meteorology, A. Thomson and Miss H. V. Miller; biology, W. H. Ball and Mrs. H. W. Graham; and drafting, Miss M. Ennis and W. C. Hendrix. Excellent progress was made in preparation of manuscripts and particularly of the many graphs necessary in presenting the results, which were about 50 per cent completed by June 30, 1932.

The narrative account, "Last Cruise of the *Carnegie*," of the seventh cruise of the *Carnegie*, including popular descriptions of the vessel's scientific work, by Paul, was published by the Williams and Wilkins Company of Baltimore. The volume was favorably received and widely distributed, nearly one thousand copies having been sold.

## PHYSICAL OCEANOGRAPHY

Sverdrup was kept informed of the progress of the discussions. He revised all the horizontal charts showing the observed data and entered lines of equal values on them. He made additions to his discussion of the physical oceanographic results and returned his finally revised manuscript to the office in June 1932. While in Berlin to present several lectures on the data obtained by the *Carnegie* in the Pacific, he took opportunity to discuss the circulation in the Atlantic and Pacific oceans with the oceanographers of the *Meteor* Expedition, especially with Dr. Defant and Dr. Wüst. The latter pointed out that according to the observations of the *Meteor* in Drake Strait an inflow of water to the Pacific from the Atlantic takes place through Drake Strait at a depth somewhat greater than 500 meters. The observations of the *Meteor* were courteously placed at the disposal of Sverdrup for the examination of this feature. He agreed with Dr. Wüst's opinion and prepared an addition to his manuscript on the physical oceanography of the Pacific, modifying his previous view as to the origin of the deep-water of that ocean. This included the deep-water from Drake Strait as one of the possible components in the mixing which results in the deep-water of the Pacific, holding open the further possibility that the deep-water entering from Drake Strait may flow to regions which were not covered by the investigations of the *Carnegie*.

At the meeting of the Chr. Michelsen Institute in Bergen, March 15, 1932, Sverdrup, in a review of his work of the preceding year, emphasized the importance of the *Carnegie* data in the Pacific to the understanding of the circulation around the Antarctic Continent and of the peculiar equatorial counter-current.

The finally revised manuscripts on sounding-velocities and on sonic-depth data were completed by Soule. He also prepared the section "Oceanic Instruments and Methods," of the National Research Council

manual of oceanography published in June 1932, as one of the Council's series on the physics of the Earth; this contribution was based largely upon the equipment assembled for the *Carnegie* and improvement of oceanographic methods developed aboard that vessel.

The discussion of the gravity-work done on the *Carnegie* was well advanced by Forbush. The loss of the vessel so soon after the installation of the Meinesz apparatus at San Francisco had hardly afforded sufficient opportunity to effect that improved technique acquired only after a reasonable period of experience. Thus the contribution in number of new gravity-stations determined in the last two months of the cruise is not great. The discussion shows that, in spite of the difficulties inevitable in this first attempt to observe gravity on a sailing-vessel, a few successful observations were obtained. The discussion doubtless will be helpful in connection with future use of gravity-apparatus aboard surface-ships.

Miss Clarke, with advice and suggestions of Bartels, completed the harmonic analyses of air-pressure, air-temperature, sea-surface temperature and relative humidity. The completion of the discussion of barometric data brought out the differences in amplitude and phase of the waves of air-pressure over oceans, islands and continents, and their relation to temperature-conditions (see abstract in last section of this report). She has assembled a large amount of reference-material in preparation for the final discussion of the meteorological results of Cruise VII of the *Carnegie*.

A. Thomson, who as Director of the Apia Observatory has had a wide experience in pilot-balloon work, with the assistance of Miss Clarke, prepared for publication the pilot-balloon data obtained by the *Carnegie*. The manuscript giving tables and graphs of the material was completed and is briefly abstracted in the last section of this report. The final drawings for graphs summarizing the upper-wind conditions are in progress.

#### CHEMICAL OCEANOGRAPHY

By courtesy of the Director of the Scripps Institution of Oceanography at La Jolla, California, Graham discussed in collaboration with Dr. E. G. Moberg of the Scripps staff during February to June 1932 the chemical results obtained aboard the *Carnegie* in 1928-29. The six manuscripts of these discussions were practically completed and the results are: (A) The Scope and Methods of the Chemical Program of the *Carnegie* (Graham and Moberg); (B) The Presentation of the Chemical Data Obtained by the *Carnegie* (Graham and Moberg); (C) The Distribution of Phosphates in the Sea (Graham and Moberg); (D) The Distribution of Silicate in the Sea (Graham and Moberg); (E) The Distribution of Hydrogen-Ions in the Sea (Graham and Moberg); and (F) The Distribution of Dissolved Oxygen in the Sea (Moberg and Graham).

The rapid progress made in these discussions was only possible because of the facilities extended by the Scripps Institution of Oceanography, and thanks are due Dr. Vaughan as Director of Scripps, who granted the privilege accorded us, and to other associates of the staff at La Jolla, who assisted and contributed so much in the discussions. Dr. H. B. Bigelow of the Woods Hole Oceanographic Institution, and Sverdrup and Soule of

the Department, have made suggestions for certain revisions in the manuscripts—suggestions indicated by biological and physical aspects.

#### BOTTOM-SAMPLES

The chemical analyses of bottom-samples were completed and reports submitted early in the year by the Sharp-Schurtz Company. Copies were promptly supplied the Scripps Institution of Oceanography and the Geophysical Laboratory of the Carnegie Institution of Washington.

Following the completion of the determinations of the mechanical analyses of the samples, as reported last year, in the sediment laboratory of the Scripps Institution, Dr. Vaughan reported that the work preliminary to the description of the samples was completed and that Roger R. Revelle had begun the actual description of them during the latter part of August. It is expected that a report on them will be finished in 1932. It is intended to subject the fine fractions of these sediments to X-ray analysis at Scripps in the expectation of getting at least an approximate idea of the mineral constituents of these fractions of the sediments, the particles of which are too small for identification by ordinary microscopic methods.

The manuscript of the results on the radium-content of the *Carnegie* bottom-samples undertaken by Dr. C. S. Piggot of the Geophysical Laboratory was completed by him. The important results of Dr. Piggot's investigation are abstracted in the last section of this report.

The preparation of manuscript by Dr. A. Mann on the diatoms is reported by him to be well advanced.

#### BIOLOGICAL SAMPLES

The sorting and gross classification of the biological specimens contained in the tow-net samples collected by the *Carnegie* were completed in August 1931 by Graham with the assistance of Ball and Mrs. Graham. The specimens were sent to various cooperating taxonomists as indicated in last year's report. There are still remaining for distribution the following groups: Amphipoda, 458 sample bottles; Decapoda, 398 sample bottles; Mollusca except Cephalopoda, 432 sample bottles; Platyhelmintha, 5 sample bottles; Stomatopoda, 31 sample bottles. Since the last report Captain A. J. Totton of the British Museum has undertaken to report upon the Siphonophores in connection with his examination of the specimens of the *Discovery* Expedition, Dr. H. B. Bigelow of the Woods Hole Oceanographic Institution upon Medusæ, Dr. H. S. Hopkins of the New York University upon Pyrosomidæ, and Dr. Waldo Schmitt of the United States National Museum upon Appendicularia. Of the over 7000 separations of specimens there are now less than 20 per cent not distributed for identification; it is hoped that for the majority of these early distribution may be effected for report.

Reports on the identifications have already been submitted on the following collections: Porifera by M. W. de Laubenfels; Pyrosomidæ by Dr. H. S. Hopkins; Insecta by Dr. Harold Morrison of the Bureau of Entomology of the United States Department of Agriculture; and Halobates by Dr. H. G. Barber of the same Bureau.

Dr. Charles B. Wilson reports good progress in the identification and study of the Copepods. He finds few of the station-samples to contain



less than ten species and many, especially those taken in the Pacific, have from 50 to over 100 species. Complying with his request, he was supplied with copies of the final tabulations giving the oceanographic and chemical results obtained at each station. He regards these factors of temperature, salinity and phosphorus-content of paramount importance in these days of advanced investigation.

From October 1931 to February 1932, Graham was occupied at the Hopkins Marine Station at Pacific Grove, California, beginning a study of the Dinoflagellata of the *Carnegie* plankton-collection. This group of organisms is being studied from the standpoints of taxonomy, geographic distribution and evolutionary significance of skeletal variations. This frequently entails very detailed morphological studies. Dr. T. Skogsberg is lending his expert assistance in the prosecution of this work. The facilities of his library and laboratory have been made available for the work through the kind cooperation of the Hopkins Marine Station. About three hundred camera-lucida working-sketches were made. Thirty-four species were recorded and carefully drawn, and a statistical study of their occurrence made. Some detailed morphological work was done on the ventral area of one species, *Peridinium pallidum* Ost.

Through a thorough study of the *Carnegie* chemical data, a good insight was obtained into the factors controlling the distribution of certain chemical substances which are involved in the metabolism of the sea. An analysis of the distribution of these substances was made for a large part of the north, tropical and southeastern Pacific, as well as in previously unexplored parts of the Atlantic.

#### COOPERATION IN OCEANOGRAPHIC WORK

At the beginning of the report-year, Soule was in Bergen, Norway, occupied with preparations for the *Nautilus* Expedition. As elsewhere reported, the *Nautilus* reached Bergen on August 1 and was joined there by Sverdrup, chief of the scientific staff, Soule and Villinger. Departing from Bergen on August 5, stops were made at Tromsø and Skjervøe en route to Advent Bay, Spitzbergen, whence the Expedition left for the ice, August 18. Because of the early loss of the horizontal rudder of the submarine, the Expedition unfortunately could not realize its aim to traverse the Polar Basin and could not penetrate the ice-pack, but had to confine operations to its border. Tests of the mechanical equipment were made and the larger part of the proposed scientific program was tried with such success as to demonstrate the feasibility of such a program on any future Arctic submarine expedition. The *Nautilus* returned to Advent Bay on September 8. The following results were obtained during the three weeks: One magnetic station; 8 bottom-samples; 8 gravity-stations; 8 oceanographic stations including measurements of temperature and collections of water-samples and of micro-biological specimens; 264 sonic soundings. While in Bergen, September 17 to October 3, Soule assisted with the reduction of the data obtained. He reported in Washington on October 14.

Sverdrup wrote a narrative of the Expedition in Norwegian. Three papers by Sverdrup and one by Soule on different phases of the scientific work were prepared as follows: (A) Scientific Work on the Wilkins-Ellsworth Arctic Expedition 1931 (Sverdrup); (B) the Route of the *Naut-*



*ilus* between August 19 and September 7, 1931 (Sverdrup); (C) Echo-Sounding on the Arctic Submarine *Nautilus* (Soule); and (D) Oceanographical Results (Sverdrup). These four papers were sent to the Woods Hole Oceanographic Institution for publication in its proposed Journal of Oceanography.

### INSTRUMENT-SHOP

The time—about 12,400 man-hours for the year—of the shop-personnel (Steiner, Lorz, Haase, A. Smith and T. Huff) under direction of C. Huff, was devoted to the construction of new equipment and experimental apparatus, to the repair and improvement of standard instruments and apparatus, and to stock, special and miscellaneous items.

A complete power-equipment was designed, assembled and shipped to the Huancayo Observatory. This included a generating unit, a motor-generator set and a control-switchboard. The generating unit consists of a Ford model A engine and a General Electric 9-kilowatt, 3-phase, 60-cycle, 230-volt generator operating at 1800 R.P.M. directly coupled to the Ford unit. The motor-generator set is a 2-unit General Electric set consisting of a 220-volt, 3-phase, 60-cycle induction-motor rated at 5-horsepower and coupled to a direct-current, shunt-wound generator delivering 25 amperes at 140 volts to charge a bank of Exide storage-batteries. The switchboard has two panels, one for the control of the main-generator and distributing circuits and the other for the control of the motor-generator and battery-charging circuits. Alternating-current from the main-generator is also used for operating the short-wave transmitter and receiver.

Good progress was made on the transmitters, receivers and oscillographs designed for the determination of height of the ionized regions (Kennelly-Heaviside layer) in the upper atmosphere. The conductivity-apparatuses 9 and 10 were completed. These involved the construction of two similar units for the measurement of positive and negative conductivity. Experimental equipment was made for the investigations in atmospheric pollution, dynamic deviation, high voltage, seismology and electromagnetic methods to determine the magnetic elements.

A stock of recorder-drums and driving clocks was made according to a new design which eliminates back-lash completely. This is accomplished by altering a standard two-spring clock-movement so that one of the springs drives the drum directly and the other spring drives the gear-train in the usual manner. The drum-driving spring, however, is also connected to the gear-train through a special gear so that the drum rotates once in 25 hours. Preparation and improvement of the magnetographs and other magnetic and electric equipment for the Polar Year stations at College and Point Barrow, Alaska, were made. Considerable time was given to preparation and installation of the annual exhibit (including assistance to other departments of the Institution), and to the maintenance of buildings and site at Washington.

### MISCELLANEOUS ACTIVITIES

*Activities in scientific bodies and lectures*—An Institution series of three illustrated lectures concerning the magnetic field of the Earth and its atmosphere was given March 8, 15 and 22, 1932, in Washington. These

were: "*Time-Changes of the Earth's Magnetic Field*" by Fleming; "*Cosmic Disturbances of the Earth's Magnetic Field and Their Influence upon Radio Communication*" by Kennelly; and "*Tides in the Atmosphere*" by Bartels. These were published in the June, July and August 1932 numbers of Scientific Monthly.

Staff-meetings to discuss various phases of progress in the fields of the Department were held in its library biweekly from October 1931 to May 1932. The personnel of the Division of Terrestrial Magnetism and Seismology of the United States Coast and Geodetic Survey took active part in these meetings, as also interested men from the United States Bureau of Standards and the Naval Research Laboratory.

Bartels spoke at the staff-meeting of the United States Bureau of Standards November 13, 1931, on "*Statistics in Geophysical Research*," discussing particularly the characteristic features of geophysical research in comparison with laboratory physics.

*Exhibit*—The Department's contribution to the Institution's annual exhibit in December related to variations in the Earth's magnetic force and their relation to the Sun.

*Library*—Throughout the report-year Harradon, in charge of the library, continued the established practise of acquiring all new publications bearing on the various aspects of terrestrial magnetism and electricity as well as on closely allied subjects which come within the range of the Department's interests. To some extent the general course of investigation oriented more intensively than in past years the trend of acquisition toward the subjects of atomic and nuclear physics, fundamental mathematics and polar exploration.

The total number of accessioned books and publications on June 30, 1932, was 19,044. This total does not, however, indicate in any way the number of titles added to the card-catalogue during the year, since it is a matter of library-routine to card, classify and incorporate in the author- and classification-indexes all papers dealing with terrestrial magnetism and electricity, as well as important articles on any topic having a potential bearing on the present or projected work of the Department. These titles are taken chiefly from the current scientific journals, of which over 75 are regularly on file in the library. As in previous years much assistance was given in connection with the publication of the Journal of Terrestrial Magnetism and Atmospheric Electricity. The detailed annotated bibliography of publications on terrestrial magnetism and electricity, and allied subjects, was continued.

*Office*—Chief Clerk Smith, Property Clerk Capello, and their assistants Kolar, Moats and Dixon, gave constructive service as in previous years in their responsibilities for the business management of the office and correspondence. Dixon, who served so well in the Department's clerical work during the past fifteen years, having reached the age of sixty-five, retired March 31, 1932, and was succeeded by Moats.

Kolar has continued in charge of the files of official correspondence and of the stock and distribution of Department publications. The list of the latter for the year ended December 31, 1931, compiled by him, indicates

that the number of publications by the various members of the Department had reached, at that date, a total of over 1100.

Extensive correspondence and numerous informal discussions of various problems in the fields of terrestrial magnetism, terrestrial electricity (particularly earth-currents and earth-resistivity), and oceanography, with investigators or other interested persons, constituted a considerable and, it is hoped, a worth-while activity of the Department.

### ABSTRACTS OF PUBLICATIONS, LECTURES AND PROGRESS-REPORTS<sup>1</sup>

For those investigations of which published accounts have appeared, abstracts are generally omitted. In a few cases, however, abstracts are given here because of the relatively greater importance and significance of the conclusions drawn in the papers. Abstracts of reports on progress of current researches are given since brief accounts of current work of individual members of the staff will be helpful to their colleagues in like fields by informing them of preliminary results in so far as they appear significant to current research in our fields.

The influence of hydrostatic pressure on the critical temperature of magnetization for iron and other materials. L. H. Adams and J. W. Green. *Phil. Mag.*, vol. 12, 361-380 (August 1931); *Terr. Mag.*, vol. 36, 161-169 (September 1931).

Geophysical stereograms. J. Bartels. *Terr. Mag.*, vol. 36, 187-198 (September 1931).

Terrestrial-magnetic activity and its relation to solar phenomena. J. Bartels. *Terr. Mag.*, vol. 37, 1-52 (March 1932).

The chief results of this paper are based on a diagram which represents terrestrial-magnetic activity day by day by means of suitable symbols, arranged in rows of 27 in order to show the influence of the Sun's rotation. It shows that magnetic activity 1906-31, as expressed by the international character-figures, is dominated by pronounced sequences of 27-day recurrences of quiet or disturbed days. Some disturbed sequences persist through several weeks in which spots are absent. Great storms often appear isolated; their solar origin has already been proved in some cases by their connection with observed solar eruptions, and it is to be hoped that such cases will become more numerous when Dr. Hale's program of continuous solar observations with spectrohelioscopes will be realized. For the minor degrees of magnetic disturbances (international character-figures between say 0.8 and 1.6) the solar origin is established by their occurrence in 27-day sequences. There is a marked change in the length of the 27-day sequences in magnetism between the end of an 11-year cycle and the beginning of a new cycle; the sequences are longest—up to a year—near the end of the cycles, when the sunspots are nearest to the Sun's equator, while the new cycle begins with short sequences.

Similar diagrams were drawn for some measures of solar activity, relative sunspot-numbers and character-figures of solar phenomena. They show, of course, the solar rotation also by approximate 27-day sequences. There appears, however, a significant discrepancy if the diagrams are compared and if it is attempted to coordinate the active regions on the Sun as directly observed to those inferred from magnetism, even if the possi-

<sup>1</sup>The abstracts of progress-reports included in this section are only those not summarized in the preceding portion of the report.



bility of a time-lag is considered. This leads to the following interpretation: Certain restricted parts (*M*-regions) of the Sun's surface are responsible for terrestrial-magnetic disturbances, very likely by emitting corpuscular radiation. The lifetime of these regions is limited, up to a year, though considerably longer than that of sunspots. The individual *M*-regions can as yet only be traced by their effect in terrestrial-magnetic activity; they are certainly not identical with sunspots or other features of the Sun as observed by visual, photographic or spectroscopic means. In this way, terrestrial magnetism has obtained a purely astrophysical significance. The frequency and intensity of the *M*-regions, taken in annual means, varies, however, in the same 11-year cycle as the sunspots.

The annual variation of terrestrial-magnetic activity, with its maxima about the months of March and September, is discussed, on the basis of a new series of monthly means of magnetic activity (*u*-measure), 1872-1930, by means of the method of the harmonic dial and also by using the fact that the northern and the southern hemispheres of the Sun show, in some years, persistent differences in spottedness. Both methods make it improbable that the two equinoctial maxima are simply related to the inclination of the Sun's axis toward the ecliptic. These negative results form a puzzling contradiction to the usual explanation of this semiannual wave in magnetic activity, which was based on the average distribution of spots in heliographic latitude (few spots on the solar equator itself) and maintained that the Earth in September is nearer the range of radial corpuscular streams from northern sunspots and in March is nearer the range of streams from southern sunspots.

The statistical aspect of correlating monthly and annual means of two variables is discussed, and general formulæ linking correlation-coefficients for monthly means with those for annual means are derived and illustrated in a diagram based on the conception of the monthly means as the result of an "explosion" of the annual means.

Linear relations between the annual means of various measures of terrestrial-magnetic activity (*u*-measure, international character-figures) and of solar activity (relative sunspot-numbers, areas of sunspots and of faculæ) are established and used for a discussion of the homogeneity of these measures. Noticeable discrepancies are the abnormally high areas of faculæ in 1892 and of the relative sunspot-numbers in the years 1916-18, which seem to be about 10 units higher than the simultaneous sunspot-areas suggest.

The introduction of the new character-figures for solar phenomena (solar indices), available since 1928 for bright and dark hydrogen lines and for calcium flocculi, does not improve the relations between terrestrial-magnetic and solar phenomena already obtained by using the relative sunspot-numbers. The main reason is found in the strong correlations which exist between various measures of solar activity and which deprive the new solar indices of their statistical independence.

L'activité du magnétisme terrestre et ses relations avec les phénomènes solaires. J. Bartels. Cong. Internat. d'Electricité, Paris, 11<sup>e</sup> Section, Comm. No. 3-C-1, 12 pp. (1932). [Prepared for International Electrical Congress, Paris, July 1932.]

Erdmagnetische Tätigkeit und ihr Zusammenhang mit Sonnenphänomenen. J. Bartels. [Presented at the Astrophysikalisches Colloquium im Einstein-Institut, Potsdam, June 14, 1932.]

Einige Beziehungen zwischen dem Erdmagnetismus und Vorgängen auf der Sonne. J. Bartels. [Presented at the meeting of the Zweigverein der Deutschen Meteorologischen Gesellschaft, Berlin, June 28, 1932.]



- Magnetism and the Sun. J. Bartels. [Presented at Carnegie Institution of Washington, Washington, D. C., December 13, 1931.]
- Erdmagnetismus und Polarlicht. J. Bartels. [Fourteen lectures presented during 1932 summer term at Berlin University.]
- Statistics in geophysical research. J. Bartels. [Presented at United States Bureau of Standards, Washington, November 13, 1931.]
- Tides in the atmosphere. J. Bartels. [The third in a series of three lectures concerning the magnetic field of the Earth and its atmosphere, delivered at the Carnegie Institution of Washington, March 22, 1932. Also presented in modified form at the Physical Colloquium, Princeton University, Princeton, New Jersey, December 3, 1931.]
- A typical case of variability of the quiet-day diurnal variation in terrestrial magnetism and earth-currents at Watheroo. J. Bartels and W. J. Rooney. *Terr. Mag.*, vol. 36, 53-55 (March 1932).
- Annual report of the Director of the Department of Terrestrial Magnetism, Carnegie Institution of Washington. Louis A. Bauer and J. A. Fleming. *Carnegie Inst. Wash. Year Book* No. 30, 1930-1931, 281-370 (1931).
- On the hyperfine structure of heavy elements. G. Breit. *Phys. Rev.*, vol. 38, 463-472 (August 1, 1931).

Calculations show the necessity of considering the relativistic corrections for the interaction between the electron and the nuclear spin. Agreement with experiment is improved by making these corrections. Whether experiment and theory agree exactly or not is still an open question. There is some evidence that the forces between the electron and the nucleus are not entirely magnetic in their origin, although in some cases later work by Bacher (based on above calculations) showed that magnetic forces are sufficient for the explanation of observed hyperfine structures.

- Dirac's equation and the spin-spin interactions of two electrons. G. Breit. *Phys. Rev.*, vol. 39, 616-624 (February 15, 1932).

Previous work indicated that quantum electrodynamics of Dirac-Heisenberg-Pauli may be applied to the discussion of spin-spin interactions experimentally observable in the fine structure of *He* and *Li*<sup>+</sup>. Some of the fundamental defects and limitations of the general theory made the results of the calculations ambiguous. Comparison with experiment indicated the correct way of using the theory. The above paper formulates the calculations avoiding the ambiguity and leads to results in agreement with experiment.

- A remark on Gamow's treatment of radioactive disintegration. G. Breit. (Abstract) *Phys. Rev.*, vol. 40, 127 (April 1, 1932).
- Measurement of nuclear spin. G. Breit and I. I. Rabi. *Phys. Rev.*, vol. 48, 2082-2083 (December 1, 1931).
- American *URSI* broadcasts of cosmic data. K. B. Clarke. *Terr. Mag.*, vol. 36, 258-259 (September 1931); 358-360 (December 1931); vol. 37, 85-89 (March 1932); 189-192 (June 1932).

- Diurnal waves of air-pressure over the oceans from observations made on Cruise VII of the *Carnegie*. K. B. Clarke.

The methods of observing and recording the hourly values of air-pressure, and of correcting and compiling these values are discussed. Twenty-four hourly mean values were formed for each ten degrees of latitude and the departures from these means subjected to harmonic analysis. The resulting coefficients represent the amplitude and phase at certain mean latitudes of the 24-hourly, 12-hourly, 8-hourly and 6-hourly waves of pressure that pass around the world each day. These harmonic coefficients are diagrammatically represented on the "harmonic dial."

The amplitude and phase of the 24-hourly wave are irregular, due to the dependence upon temperature-conditions. The amplitude from *Carnegie* values for a mean of latitudes 5° north to 5° south is 0.924 mm. The value decreases toward the poles as this wave becomes masked by the pressure-waves accompanying cyclonic disturbances.

*Carnegie* data and those from other ships confirm the belief that the amplitude of the semidiurnal wave is less over the oceans than over the land. Supposing the mean values from Simpson to represent continental conditions, the magnitude of difference in amplitude of the 12-hourly wave between continent and ocean is approximately 0.1 mm. The amplitudes at six selected ocean-island stations average about 0.05 mm. greater than those over the open ocean at the same latitudes.

The 8-hourly and 6-hourly waves have a seasonal variability in amplitude and phase. Since the *Carnegie* alternated hemispheres, the results for any mean latitude-zone include days in different seasons. This makes analysis of these waves difficult. Their presence is real, however, and the seasonal variation is evident. The mean amplitude of the 8-hourly wave for the southern summer in southern latitudes 25° to 35° is comparatively large, 0.114 mm., while the smallest amplitude in this harmonic, 0.007 mm., appears at 25° to 35° north where days during May and October minimize the effect of a larger amplitude during the days of June and August.

The relationships between air-pressure and temperature-waves for the same mean latitudes over the ocean and for certain island stations are briefly discussed.

Observations of the Aurora Australis, Byrd Antarctic Expedition, 1929. F. T. Davies. *Terr. Mag.*, vol. 36, 199-230 (September 1931).

Exhibit of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Variations in the Earth's magnetic forces and their relation to the Sun. Department of Terrestrial Magnetism. Carnegie Institution of Washington, Exhibition Program for 1931, 7-9 (December 1931).

Preliminary note on a measure of magnetic activity using an ordinate-integrator. C. R. Duvall. C. R. Assemblée de Stockholm, août 1930. *Union Geod. Geophys. Internat.*, Sec. Mag. Electr. Terr., Bull. No. 8, 275-280 (1931).

Magnetic activity—Some results of the measure adopted at Stockholm. C. R. Duvall. *Terr. Mag.*, vol. 36, 311-314 (December 1931).

Magnetic secular variation for epoch 1930. C. C. Ennis. *Terr. Mag.*, vol. 36, 315-317 (December 1931).

Isopors and isoporic movements. H. W. Fisk. C. R. Assemblée de Stockholm, août 1930. *Union Geod. Geophys. Internat.*, Sec. Mag. Electr. Terr., Bull. No. 8, 280-292 (1931).

Magnetic secular-variation and solar activity. H. W. Fisk. *Internat. Res. Council*, Third Rep. Comm. Solar Terr. Relationships, 52-59 (1931).

Summary of reports received on magnetic and electric work of organizations in the United States during 1931-32. H. W. Fisk. *Nat. Res. Council*, Trans. Amer. Geophys. Union, 13th annual meeting, 145-147 (June 1932).

The unsymmetrical distribution of magnetic secular-variation. H. W. Fisk.

The phenomenon of the concentration of a large part of the total secular change of a magnetic element around certain centers and within limited areas produces an asymmetry of distribution of such changes which is best displayed by use of the isoporic charts. Numerical measures of the unequal distribution of the changes in horizontal intensity in both latitude and longitude were found by a simple summation of the changes on the isoporic chart of that element. The superficial area of the Earth between latitude 75° north and 65° south was divided into small elementary areas and the

mean value of  $\Delta H/H$  found for each. Suitably summed it was found that the horizontal intensity is diminishing at the average rate of about one part in 900, or the mean value of  $\Delta H/H$  for the whole Earth excluding the unknown polar caps which constitute less than 7 per cent of the whole is  $-0.00111$ . This is compared with the conclusion of Bauer in 1923 that the annual decrease of horizontal and equatorial components of the Earth's field from 1885 to 1922 has been as much as one-tenth of one per cent. The horizontal component is increasing over only about 21 per cent of the entire surface, and not less than nine-tenths of that 21 per cent lies north of the equator. The lack of symmetrical distribution in longitude and in latitude was shown graphically. The average value of  $\Delta H/H$  in each lune between meridians spaced at  $20^\circ$ -intervals was found and plotted as an ordinate with longitude as abscissa. The relatively small values of positive as compared with negative values of the ratio is thus shown, as well as the small secular-change activity in those longitudes covered by the Pacific Ocean as compared with those upon which the great continents lie. When averages are taken over zones instead of lunes and plotted against latitude from  $75^\circ$  north to  $65^\circ$  south in a similar way, the positive values of  $\Delta H/H$  disappear at a short distance south of the equator, while the negative values, always greater than the positive values in all zones, have much higher average values in the southern than in the northern hemisphere. There is thus a striking lack of symmetry in either of these two coordinate directions.

A graphical comparison is made between the distribution of land around the Earth according to longitude and the sum without regard to sign of the values of  $\Delta H/H$  taken in the same direction. When these two curves are smoothed to relieve them of inevitable inequalities, there is a suggestive similarity which might have been anticipated from the low values of annual changes generally over the Pacific hemisphere. A graph representing the distribution with longitude of what may be called secular-change activity, roughly estimated by the density of the lines on the declination, inclination and horizontal-intensity isoporic charts, conforms to the other two graphs and expresses in another way the same conclusion, namely, that the changes in the direction and intensity of the magnetic field as measured at the Earth's surface are much greater in the hemisphere containing Europe, Africa, the Atlantic Ocean and South America than in the opposite one. The general conclusion is that the most important present line of attack of the subject of secular variation is to concentrate attention on the study of changes taking place in those areas in which they seem to be localized and probably having their origin in causes limited in action to the regions where these greater changes are manifest.

On the distribution of permanent repeat stations. H. W. Fisk and J. A. Fleming. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 293-299 (1931).

Report by the Department of Terrestrial Magnetism, Carnegie Institution of Washington, to the Stockholm Assembly on work done since the Prague Assembly. J. A. Fleming. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 58-76 (1931).

Comments on the agenda for the Stockholm meeting of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union. J. A. Fleming. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 218-235 (1931).

Observations of terrestrial magnetism and atmospheric electricity on the last cruise of the *Carnegie*. J. A. Fleming. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 235-241 (1931).



- Latest annual values of the magnetic elements at observatories. J. A. Fleming. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 244-264 (1931).
- The magnetism of the Earth. J. A. Fleming. Sci. Mon., vol. 33, 74-77 (July 1931); also printed as Chapter 9 in *Science Today*, New York, Harcourt, Brace and Co., 59-67 (1931).
- The Jubilee International Polar Year. J. A. Fleming. Sci. Mon., vol. 34, 375-380 (October 1931).
- Summary of the year's work, Department of Terrestrial Magnetism, Carnegie Institution of Washington. J. A. Fleming. Terr. Mag., vol. 36, 333-339 (December 1931).
- Researches of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington bearing on solar activity and the Earth's magnetic and electric fields. J. A. Fleming. Internat. Res. Council, Third Rep. Comm. Solar Terr. Relationships, 60-64 (1931).
- Compilation of oceanographic results, *Carnegie* cruise, 1928-1929. J. A. Fleming. Rep. Comm. Submarine Configuration and Oceanic Circulation, Nat. Res. Council, 71-81 (1931).
- Expeditions and oceanographic work in the polar regions. J. A. Fleming. Rep. Comm. Submarine Configuration and Oceanic Circulation, Nat. Res. Council, 81-88 (1931).
- The proposed Second International Polar Year 1932-1933. J. A. Fleming. Geog. Rev., vol. 22, 131-134 (January 1932).
- Louis Agricola Bauer, 1865-1932. J. A. Fleming. Science, n.s., vol. 75, 452-454 (April 29, 1932).
- International Union of Geodesy and Geophysics. J. A. Fleming. Standards Year Book, 1932, Dept. Comm., Bur. Stan. Misc. Pub. No. 133, 70-71 (1932).
- American Geophysical Union. J. A. Fleming. Standards Year Book, 1932, Dept. Comm., Bur. Stan. Misc. Pub. No. 133, 71-74 (1932).
- International Polar Year 1932-33. J. A. Fleming. Rep. Div. Geol. Geog., Nat. Res. Council, App. Y, 3 pp. (1932).
- Distribution à travers le monde des observatoires magnétiques et des stations pour l'étude de la variation séculaire. J. A. Fleming. Cong. Internat. d'Electricité, Paris, 11<sup>e</sup> Section, Comm. No. 2-C-1, 11 pp. (1932). [Prepared for International Electrical Congress, Paris, July 1932.]

The need of international cooperation in extending the existing network of magnetic observatories for the solution of problems in terrestrial magnetism, particularly of secular variation, and of maintaining the continuity of observational data is emphasized. The possible locations of additional fixed observatories are discussed and suggestions made. The opportunity of making permanent a number of equatorial and polar observatories proposed for occupation by the International Polar Year Commission for the Second Polar Year program of August 1932 to August 1933 is suggested as a means to improve the present world-distribution of such stations at a minimum of effort and expense in a way serving the requirements for advances in scientific interpretation of magnetic phenomena of the Earth and of its atmosphere and serving also practical requirements of modern geophysical research. Tentative charts suggesting also a network of additional observatories and permanent repeat-stations to supplement the data already obtained in the study of magnetic secular-variation and its cosmical relations are submitted. Such a network of stations because of the extent of our natural laboratory—the Earth—can only be realized by systematic and coordinated efforts on the part of all nations. It is only in such cooperation that effective investigation of world-wide magnetic phenomena may be eventually realized to the ultimate scientific and practical utilization of



mankind. Various conditions bearing on the selection and distribution of the minimum number of additional observatories and of field-stations are summarized.

- Time-changes in the Earth's magnetic field. J. A. Fleming. *Sci. Mon.*, vol. 34, 499-530 (June 1932). [The first in a series of three lectures concerning the magnetic field of the Earth and its atmosphere, delivered at the Carnegie Institution of Washington, March 8, 1932.]
- Transactions of the American Geophysical Union, thirteenth annual meeting, April 28 and 29, 1932. J. A. Fleming, Editor. Nat. Res. Council, 401 pp. (June 1932).
- Magnetic investigations of the Carnegie Institution of Washington, May 1931 to April 1932. J. A. Fleming. Nat. Res. Council, Trans. Amer. Geophys. Union, 13th annual meeting, 148-152 (June 1932).
- The seismological station at the Huancayo Magnetic Observatory in Peru. J. A. Fleming. [Presented at the meeting of the Eastern Section of the Seismological Society of America, Philadelphia, May 2, 1932.]
- Report of work of Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, 1928-1930. J. A. Fleming and H. W. Fisk. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 48-53 (1931).
- The importance of atmospheric-electric observations at sea. O. H. Gish. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 345-346 (1931).
- Some general information which should be included in reports of atmospheric-electric observations. O. H. Gish. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 347-349 (1931).
- Apparatus for the study of the Earth's crust. O. H. Gish. U. S. Patent No. 1,813,845, 6 pp. (July 7, 1931).
- Systematic errors in measurements of the ionic content and the conductivity of the air. O. H. Gish. *Beitr. Geophysik*, vol. 35, 1-5 (1932).
- Les courants électriques naturels de l'écorce de la Terre et leur rapport avec le magnétisme terrestre. O. H. Gish. Cong. Internat. d'Electricité, Paris, 11<sup>e</sup> Section, Comm. No. 1-C-2, 21 pp. (1932). [Prepared for International Electrical Congress, Paris, July 1932.]

A resolution passed by the International Electrical Congress at Paris 50 years ago stimulated the investigation of the natural electric currents (earth-currents) which flow in the Earth's crust. Important advances in the knowledge of this class of phenomena have been made since that time. These are briefly described and the principal conclusions which at present seem justified are stated. Some of these conclusions follow:

(a) The measurements of earth-currents give no evidence of the existence of electric currents of such character and magnitude as would be required to produce the major part of the Earth's magnetic field.

(b) The regular diurnal changes in earth-currents are approximately of the character to be expected if these and diurnal variations in the Earth's magnetism are induced by a system of electric currents in the high atmosphere.

(c) The relation between the irregular changes, disturbances and so-called storms of earth-currents and the corresponding magnetic changes is often not of the character found for the diurnal variation, but is rather that which would be expected if the irregular earth-currents were the direct cause of the magnetic changes.

(d) Changes in earth-currents, those in terrestrial magnetism, as well as those in polar lights, show a definite tendency to recur after a period of about 27 days, which is about the interval for the reappearance of a sunspot on the earthward side of the Sun.

(e) The variations in earth-currents change from year to year in a manner very similar to that of the magnetic variations, and both of these increase or decrease on the average as the sunspot-numbers increase or decrease.

(f) Those observations which have been taken to indicate that electric currents flow predominantly from the base to the summit of mountains can probably be explained as due to a systematic change with altitude in the constitution of the soil-solutions in mountainous regions, which may give rise to a flow of current only when the electrodes and external conductor which are used in the measurements are introduced.

Principal magnetic storms, Apia Observatory (October 29-30, 1931). P. W. Glover. *Terr. Mag.*, vol. 36, 364 (December 1931).

Oceanographic results of the last cruise of the *Carnegie*. H. W. Graham. [Presented before the Scripps Institution of Oceanography, La Jolla, California, May 27, 1932.]

The distribution of plant-nutrients in the Pacific. H. W. Graham and E. G. Moberg. [Presented before the meeting of the Western Society of Naturalists with the Pacific Division of the American Association for the Advancement of Science at Pullman, Washington, June 16, 1932.]

Recent work in the Pacific by the *Carnegie* of the Carnegie Institution of Washington has shown that the fertility of the waters of the Pacific is closely allied with prevailing hydrographic conditions. The deep-water of the Pacific is very rich in such plant-nutrients as carbon dioxide, phosphates and silicates. At intermediate depths there are even greater quantities of these substances. They accumulate at these depths from the decomposition of organic detritus. In tropical and warm temperate latitudes only small amounts of these substances can reach the photosynthetic zone through convection. However, considerable quantities are brought to the surface where there is a mass upwelling of water as along the west coast of the Americas, or where there are comparatively violent and complex currents as in the equatorial regions. At higher latitudes the partial elimination of the density-gradient permits more vertical circulation. High concentrations of phosphate were found at the surface in the North Pacific East Drift for this reason and also because water from the Bering Sea probably high in phosphate flows into this current.

The hydrogen-ion concentration of sea-water furnishes an index of its carbon dioxide-content. A direct correlation was found between the hydrogen-ion concentration and the phosphate-content of the surface-waters in the Pacific. A reciprocal relationship was found between the hydrogen-ion concentration and the temperature of the surface-water further indicating that the fertile surface-waters have recently ascended from lower levels or have moved in from higher latitudes. Correlations of the vertical distribution of density and phosphate for various regions of the Pacific further showed how the distribution of plant-nutrients is dependent upon hydrographic conditions.

The effect of pressure on the magnetic inversion-point in iron and other materials. J. W. Green and L. H. Adams. (Abstract) *Jour. Wash. Acad. Sci.*, vol. 22, 279 (May 19, 1932).

Measurements of small currents using plotron tubes. L. R. Hafstad. (Abstract) *Phys. Rev.*, vol. 40, 1044 (June 15, 1932). [Presented at the meeting of the American Physical Society, Washington, D. C., April 29, 1932; also note prepared for use in the American Physical Society symposium "Electronic devices and their applications to research with special reference to radiation sensitive devices," Cambridge meeting, February 26, 1932.]

- The library of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. H. D. Harradon. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 241-242 (1931).
- Twenty-fifth anniversary of the foundation of the Observatorio del Ebro. H. D. Harradon. Terr. Mag., vol. 36, 256-258 (September 1931).
- Abstract of the Innsbruck meeting of the Commission of Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Organization and of the resolutions adopted September 21-23, 1931. H. D. Harradon. Terr. Mag., vol. 36, 319-323 (December 1931).
- Abstract of the Innsbruck meeting of the International Commission for the Polar Year 1932-33 of the International Meteorological Organization and of the resolutions adopted September 23-26, 1931. H. D. Harradon. Terr. Mag., vol. 36, 324-332 (December 1931).
- Abstract of supplementary resolutions of the International Commission for the Polar Year 1932-33. H. D. Harradon. Terr. Mag., vol. 37, 185-186 (June 1932).
- List of recent publications. H. D. Harradon. Terr. Mag., vol. 36, 264-271 (September 1931); 367-373 (December 1931); vol. 37, 93-102 (March 1932); 195-202 (June 1932).
- Ordinate-change integrator. C. Huff. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 272-275 (1931).
- Optically-compensated variometers and wide-range recorders to be used during the Jubilee Polar Year. H. F. Johnston. Nat. Res. Council, Trans. Amer. Geophys. Union, 13th annual meeting, 187-190 (June 1932). [Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 28, 1932.]
- Variations du champ magnétique terrestre aux observatoires de Watheroo et de Huancayo et leurs relations avec les systèmes de courants à l'intérieur et au voisinage de la Terre. H. F. Johnston and A. G. McNish. Cong. Internat. d'Electricité, Paris, 11<sup>e</sup> Section, Comm. No. 2-C-3, 12 pp. (1932). [Prepared for International Electrical Congress, Paris, July 1932.]

The diurnal variation of the north, east and vertical components of the Earth's magnetic force at the Watheroo and the Huancayo magnetic observatories for all days of the years 1929 and 1930 is considered with reference to the analysis made by Chapman for the year 1905. It is found that, in general, the difference between the observed values at the Watheroo Observatory and the values computed for that station from the constants of Chapman exhibit as good agreement as the data upon which the computations were based. Huancayo, however, exhibits an outstanding discrepancy when compared with the computed values, although other observatories in the surrounding region show related anomalies.

Two possible causes of this discrepancy are suggested and qualitatively discussed. The first of these hypotheses attributes the anomaly to a lower resistance encountered by the currents of the upper atmosphere while passing over Huancayo, due to the low value of the magnetic force over that region. The other explains it as being due to the comparatively high values of the vertical intensity of the permanent field over the northern part of South America and adjacent regions. The first of these appears to be insufficient to account for the phenomenon, although it may be a contributing factor. The second hypothesis is probably sufficient in itself.

Cosmic phenomena influencing the propagation of radio waves. A. E. Kennelly. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 422-437 (1931).

The modern electric age in relation to Faraday's discovery of electromagnetic induction. A. E. Kennelly. Nature, vol. 128, 356-359 (August 29, 1931).



- Report of Commission IV on "Liaison" for the period between the general meetings of 1928 (September 10-15, at Bruxelles) and 1931 (May 27 at Copenhagen). A. E. Kennelly. Internat. Sci. Radio Union, Gen. Assembly, Copenhagen 1931, 80-85 (1931).
- The present status of the magnetic-circuit units. A. E. Kennelly. *Denki-Gakkwai (Inst. Electr. Eng. of Japan)*, 25 pp. (1931).
- Recent developments in magnetic units. A. E. Kennelly. *Electr. Eng.*, vol. 51, 343-345 (May 1932).
- The work of Joseph Henry in relation to applied science and engineering. A. E. Kennelly. *Jour. Wash. Acad. Sci.*, vol. 22, 293-310 (June 4, 1932); also *Science*, n.s., vol. 76, 1-7 (July 1, 1932).
- Magnetic units. A. E. Kennelly. *Phys. Rev.*, vol. 40, 1050 (June 15, 1932).
- Cosmic disturbances of the Earth's magnetic field and their influence upon radio communication. A. E. Kennelly. [The second in a series of three lectures concerning the magnetic field of the Earth and its atmosphere, delivered at the Carnegie Institution of Washington, March 15, 1932.]
- Some common periodicities in radio transmission-phenomena. G. W. Kenrick and G. W. Pickard. *Nat. Res. Council, Trans. Amer. Geophys. Union*, 13th annual meeting, 172-179 (June 1932). [Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 28, 1932.]
- Phase interference phenomena in low-frequency radio transmission. G. W. Kenrick and G. W. Pickard. [Presented at the meeting of the International Union of Scientific Radiotelegraphy, Washington, April 29, 1932.]
- List of publications of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, 1931. J. J. Kolar. *Carnegie Inst. Wash.*, 13 pp. (December 31, 1931).
- Principal magnetic storms, Huancayo Magnetic Observatory, April to December 1931. P. G. Ledig. *Terr. Mag.*, vol. 36, 363 (December 1931); vol. 37, 90 (March 1932).
- Features of the current-system of the upper atmosphere as revealed by the diurnal magnetic variations at Huancayo, Peru. A. G. McNish. (Abstract) *Phys. Rev.*, vol. 40, 1046-1047 (June 15, 1932). [Presented at the meeting of the American Physical Society, Washington, D. C., April 29, 1932.]
- Use of automatic recording equipment in radio-transmission research. P. A. de Mars, G. W. Kenrick and G. W. Pickard. *Proc. Inst. Radio Eng.*, vol. 19, 1618-1633 (September 1931).
- Principal magnetic storms, Watheroo Magnetic Observatory, April to December 1931. W. C. Parkinson. *Terr. Mag.*, vol. 36, 363-364 (December 1931); vol. 37, 90 (March 1932).
- The diurnal variation of potential gradient—A comparison of ocean values with those obtained at the Watheroo Magnetic Observatory, Western Australia. W. C. Parkinson. [Presented before the Conference of Physicists, Mathematicians and Astronomers at Sydney, Australia, August 1931.]

The observations of electrical air-potentials made during the seventh, and last, cruise of the Carnegie Institution's survey yacht *Carnegie* are shown to agree very closely with the observations made on previous cruises by different observational methods. This confirmation of Mauchly's theory that the diurnal variation of the potential gradient is due, primarily, to a wave of 24-hour period which progresses according to universal time renders the critical examination of the records from land stations increasingly important. The values of potential gradient obtained over the seven years 1924 to 1930 at Watheroo are discussed and certain anomalies are disclosed. Special field-observations designed to ascertain the causes for these anomalies are described and plans for the continuance and extension of this field-work outlined.



The diurnal variation of the electric potential of the atmosphere over the oceans. W. C. Parkinson and O. W. Torreson. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 340-345 (1931).

The last cruise of the *Carnegie* (with a foreword by John A. Fleming). J. H. Paul. Baltimore, Williams and Wilkins Co., XIII + 331 with 198 illus. (1932).

Investigation of the distribution of some individual changes in magnetic elements during a magnetic storm. W. J. Peters. C. R. Assemblée de Stockholm août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 264-270 (1931).

Report on work of radio laboratory, Newton Centre, Massachusetts. G. W. Pickard. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 55-57 (1931).

A note on the relation of meteor showers and radio reception. G. W. Pickard. Proc. Inst. Radio Eng., vol. 19, 1166-1170 (July 1931).

Radium-content of ocean-bottom sediments. C. S. Piggot. Nat. Res. Council, Trans. Amer. Geophys. Union, 13th annual meeting, 233-238 (June 1932). [Presented at the meeting of the Section of Oceanography of the American Geophysical Union, Washington, April 29, 1932.]

The determination of radium-content of 28 samples of ocean-bottom sediments obtained by the *Carnegie* (27 in the Pacific and one in the Atlantic) was made at the Geophysical Laboratory of the Carnegie Institution of Washington, and the results are compared with similar determinations reported by Joly on 12 sediments collected by the *Challenger* and *Albatross* and by Pettersson on 28 sediments collected by the *Challenger* and *Princess Alice II*, also from the Pacific and Atlantic oceans. These comprise practically all such determinations that have been made, and the paucity of these data in comparison to the extent, importance and high radium-content of the material is emphasized. The most striking fact is the extraordinarily high concentration of radium in these sediments compared to that in ordinary rocks of the Earth's structure. Thus the average concentration in granites might be placed at about  $2.5 \times 10^{-12}$  gram radium per gram of rock and for basalts at about  $1.0 \times 10^{-12}$  gram radium per gram, while the general average of the 68 determinations on bottom-samples gives the astonishingly high figure of  $11.76 \times 10^{-12}$  gram radium per gram of dry material. Those bottoms composed mostly or entirely of red clay generally contain more radium. A mechanism for explaining the high radium-content of deep-sea sediments is suggested which does not coincide with the opinions of Joly or Pettersson.

The use of resistivity-measurements in the detection of mineralized areas. W. J. Rooney. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 352-353 (1931).

Mesures de la resistivité de la Terre et leur application à la géophysique et aux problèmes techniques. W. J. Rooney. Cong. Internat. d'Electricité, Paris, 11<sup>e</sup> Section, Comm. No. 4-C-1, 15 pp. (1932). [Prepared for International Electrical Congress, Paris, July 1932.]

A method and apparatus for the precise determination of the resistivity of undisturbed volumes of the Earth's crust with linear dimensions ranging from 1 to 600 meters or more have been developed at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The method is an adaptation of that proposed by Wenner in 1915, based on the laws of the four-terminal conductor. With four electrodes equally spaced in a straight line a measured current is passed between the outside pair and the resulting potential between the intermediate pair determined. The

volume of earth included in a given measurement has linear dimensions approximately equal to the electrode-spacing and is varied by changing the spacing. Hence the variation of recorded resistivity with depth can be determined.

The applied current is reversed periodically to minimize polarization and eliminate extraneous currents. Important features of apparatus design are: (1) Provision insuring that the potentials measured are always those corresponding to a steady state of the current and so making the method essentially a direct-current one; and (2) a guard-ring eliminating the possibility of error due to leakage from the current to the potential circuit. Recorded resistivities represent average or "effective" values, in which materials closest to the line of measurement have the greatest effect. The error of measurement is not over one-half of one per cent. Values as low as 20 ohm-cm. and as high as 5,000,000 ohm-cm. have been measured successfully.

Four extensive surveys to determine the resistivity of regions near existing systems for recording earth-current potentials in Australia, Peru, Spain and the United States, and its variation with position and depth, have been carried out. The results combined with potential-records permit evaluation of the latter in terms of current-density, make records obtained at widely separated locations directly comparable, and afford an explanation of apparent discrepancies in earlier earth-potential records. Measurements of resistivity made throughout the year have eliminated variations in ground-conductivity as a possible cause of the large seasonal variations in the activity of earth-currents shown by potential-records everywhere. Resistivity-data are also useful in the selection of sites for the electrodes of potential-measuring systems.

A study of the variations of resistivity with depth shows that certain concealed structural features, such as the distribution of materials, depth of water-table, and the contour and type of bedrock, may, under favorable conditions, be determined from such measurements. The favorable conditions required are a not too complex structure and a sufficient difference in the specific resistance of the materials comprising it. The value of a rapid method of determining these facts to the geologist, the engineer, or the prospector is apparent, and the method or modifications of it have been used for this purpose by a number of investigators.

Diurnal variation of earth-current potentials on magnetically disturbed and magnetically calm days. W. J. Rooney.

A comparison of the records of earth-current potential at Watheroo on disturbed and calm days shows a small but distinct and consistent difference in diurnal variation quite similar to that observed in the magnetic records. The records used in the comparison cover the five-year period 1924-1928. Since magnetic and electrical classifications of days give almost identical results, the former was used throughout to facilitate comparison with the magnetic records. During the hours before noon, the ordinates of the disturbed-day diurnal-variation curve are always higher than those of the calm-day curve and during the last half of the day they are correspondingly lower. The difference-curve is, therefore, essentially one of single period with an amplitude approximately the same as that of the first harmonic of the normal diurnal-variation curve. Because of the fact that the principal minimum of the mean diurnal-variation curve occurs during the morning and its principal maximum is found shortly after noon,<sup>1</sup> the amplitude of

<sup>1</sup> Terr. Mag., vol. 33, 79-90 (June 1928).

diurnal variation on disturbed days is somewhat less than that on calm days instead of greater as in the case of the magnetic records. The records for the individual months agree very closely with those for the year as a whole, as far as the type and magnitude of the difference-curve are concerned.

The records from the Ebro Observatory for the same period show, in general, a similar difference between disturbed and calm days, if the deviation of current-flow is considered with reference to the equator. The consistency of the difference-curve for the individual months of the year is not as good as at Watheroo.

- Problems in atmospheric electricity at Apia, Western Samoa. K. C. Sanderson. *Terr. Mag.*, vol. 37, 171-175 (June 1932).
- Investigating the directional properties of an amateur antenna. S. L. Seaton. *Q S T*, vol. 16, 16-17 (May 1932).
- Observations on the phosphate-content and hydrogen-ion concentration of the North Sea, the southern entrance to the Norwegian Sea, and the water south of Iceland. H. R. Seiwel. *Jour. Conseil Internat. Explor. Mer*, vol. 6, 213-231 (1931).
- Oceanic instruments and methods. F. M. Soule. *Bull. Nat. Res. Council*, No. 85, 411-454 (June 1932).
- Echo-sounding on the submarine *Nautilus*. F. M. Soule. *Bull. Ass. Field Eng., U. S. Coast Geod. Surv.*, No. 5, 67-69 (June 1932).
- Hvorledes og hvorfor med *Nautilus*. H. U. Sverdrup. Oslo, Gyldendal Norsk Forlag, 183 with illus. (1931).
- Scientific results of the Andrée Expedition. I. Drift-ice and ice-drift. H. U. Sverdrup. *Geog. Ann.*, vol. 13, 121-140 (1931).
- Die wissenschaftlichen Arbeiten auf der Wilkins-Ellsworth-Expedition 1931. H. U. Sverdrup. *Arktis*, vol. 4, 49-50 (1931).
- Diurnal variation of temperature at polar stations in the spring. H. U. Sverdrup. *Beitr. Geophysik*, vol. 32, 1-14 (1931).
- Audibility of the aurora polaris. H. U. Sverdrup. *Nature*, vol. 128, 457 (September 12, 1931).
- Fridtjof Nansen som videnskapsmann. H. U. Sverdrup. *Norsk. Geogr. Tidssk.*, vol. 3, 306-313 (1931).
- Wärmehaushalt und Austauschgrösse auf Grund der Beobachtungen der *Maud*-Expedition. H. U. Sverdrup. *Beitr. Physik frei. Atmos.*, vol. 19, 276-290 (1932).
- Arbeider i luft- og havforskning. H. U. Sverdrup. Bergen, Chr. Michelsens Inst., Beretninger II, 5, 1-22 (1932).
- Die Zirkulation in Stillen Ozean auf Grundlage der Beobachtungen der *Carnegie* Expedition. H. U. Sverdrup. [Presented before Gesellschaft für Erdkunde zu Berlin, February 15, 1932.]
- The character of the equatorial counter-currents as revealed by the observations of the *Carnegie*. H. U. Sverdrup. [Presented at Institut für Meereskunde, Berlin, February 16, 1932.]
- Als Meeresforscher mit dem Unterseeboot *Nautilus* im Nordpolargebiet. H. U. Sverdrup. [Presented at Institut für Meereskunde, Berlin, February 16, 1932.]
- The trade and antitrade wind-circulation over the South Pacific Ocean. Andrew Thomson. [Prepared for presentation before the Royal Society of Canada at its Ottawa meeting, May 27, 1932.]
- Upper-wind observations and results obtained on Cruise VII of the *Carnegie*. Andrew Thomson.

Because the route of the seventh cruise of the *Carnegie* lay across regions where no upper-air data had been obtained, the program of this cruise was extended to include observations of the upper winds by means of pilot-balloons. The Bureau of Aeronautics of the Navy Department, the Meteorological Service of the Signal Corps, the Air Corps of the Army, and



the Weather Bureau cooperated generously with the Department of Terrestrial Magnetism in carrying out this valuable program.

Between October 1928 and November 1929, 171 pilot-balloon flights were completed. Of these 110 were made within the tropics and the majority were within the trade-wind regions. Half of the total ascents reached an altitude of 3.5 km., the highest going to a computed altitude of 12,780 meters. The equipment consisted of a special marine-type theodolite with gimbals and mounting tripod, an equipment developed and loaned by the United States Navy Department; hydrogen supplied by the Navy Department; balloons, black or uncolored, in 6-inch and 9-inch sizes; and inflating balance. During the earlier part of the cruise a second observer employed a rotating chair designed by Captain Ault and a suspended sextant to help in keeping the balloon in view.

A discussion of the permanent state of the atmospheric movement as evidenced by the observations taken over large areas gives the following conclusions: The shallowness of the southeast trade-winds off the Peruvian Coast; the presence of the South American high-pressure area with strong downward currents and light horizontal movement; a great easterly drift of surface-air between 120° and 135° west and 15° and 20° south, separated from a west-northwestward moving stratum above 3.0 km. by a layer of stagnant or lightly moving air; an inflow of air from the south-southwest above the southeast trades at levels from 2.6 km. to 3.3 km. between 135° and 140° west and 15° and 20° south; and surface-winds with a northerly component between the same latitudes and from 140° west to Samoa; prevailing easterly surface-winds in the equatorial Pacific, usually east-northeast, varying in thickness from 400 to 800 meters with a mean velocity at height of 500 meters of 5 to 12 meters per second, southerly winds turning to southwest between 3.0 to 8.5 km. between 7° and 15° south above these easterly winds, and a shift to east-northeast at a height of about 6 km. between 15° to 20° north and 190° to 210° west above the east and east-southeast surface-winds; in the northeastern Pacific variable surface-winds with winds above 3.0 km. equally variable but generally opposite to the surface-direction; on the easterly part of the route between San Francisco and Honolulu northerly surface-winds becoming variable on the northern limit of the trades; steady east and northeast surface and lower-level winds between 120° to 160° west and 23° to 30° north—one high ascent at 25° north indicating a turning to southwest at high levels through southeast and south; and south of 20° north, northeast trades overrun by an easterly drift, turning to southwest through south above the easterly current.

Mention is made of the variation in velocity of the trade-winds and of the stratification due to turbulence and friction. An attempt is made to estimate the height of clouds above the ocean-surface from the disappearance of the balloons into the clouds.

The determination of geographical position for scientific observations at sea and especially in connection with magnetic work. O. W. Torreson. *Hydrogr. Rev.*, vol. 8, 112-113 (November 1931); also published in the French edition of the *Hydrogr. Rev.*, vol. 8 (November 1931).

Note on investigation of electrical conditions in the upper atmosphere. M. A. Tuve. C. R. Assemblée de Stockholm, août 1930. *Union Geod. Geophys. Internat.*, Sec. Mag. Electr. Terr., Bull. No. 8, 351-352 (1931).

High-voltage X-rays. M. A. Tuve. [Presented at the Seventeenth Annual Meeting of the Radiological Society of North America, St. Louis, December 1, 1931.]

From the known monochromatic absorption-coefficients for water, for quanta of energies 100 to 2000 kilovolts, and from published water phantom



depth-dose measurements for 200-kilovolt X-rays and for the Memorial Hospital radium-pack, the corrections due to re-scattered radiation are estimated for various depths and calculated depth-dose curves constructed for monochromatic radiation up to 2000 kilovolts. Lead is perhaps the best available filter for removing the softer components from the "white" or general X-radiation from a high-voltage X-ray tube (operated above 1000 kilovolts). The curve for monochromatic absorption-coefficients of lead is given, and the curves for calculated spectral energy distributions obtained on three assumptions as to the efficiency of production of X-rays, namely, efficiency proportional to voltage, to square root of voltage and efficiency constant. The curves for a 2000-kilovolt X-ray tube on the three assumptions do not differ greatly in shape after filtering the radiation to half value at a frequency three-fourths of the quantum limit. From the monochromatic depth-dose curves and these spectral distribution-curves after filtering it is shown that the expected depth-dose curve for a 2000-kilovolt X-ray tube does not differ greatly from that of a 200-kilovolt X-ray tube with ordinary filtering at the same skin-target distance. In fact, the calculated 10-cm. depth-dose of a 2000-kilovolt X-ray tube, filtered as above indicated and with a 50-cm. skin-target distance, is about 50 per cent of the skin-dose, and a 200-kilovolt tube with ordinary filtering can be raised from a 10-cm. depth-dose of 40 per cent to one of 48 per cent by changing from 50-cm. to 100-cm. skin-target distance! Thus, although the proportion of the *primary* radiation which reaches this depth is very different in the two cases, unless intense nuclear X-rays are excited, no extreme gain in depth-dose is to be expected by using very high voltage tubes. It is emphasized that "depth-dose" in this connection does not represent radiant energy flux nor energy absorbed from the beam, but the ordinary usage of the term to represent the empirical reading of a good small-chamber ionization meter. Biological effects may differ widely for the same depth-dose at two widely different frequencies, possibly depending on the "hardness" of the radiation present; hence no biological conclusions are to be drawn from the calculations outlined.

Recherches expérimentales sur les tubes à vide à très hautes tensions. M. A. Tuve. Cong. Internat. d'Electricité, Paris 1<sup>re</sup> Section, Rapport No. 26, 15 pp. (1932). [Prepared for International Electrical Congress, Paris, July 1932.]

The fundamental nature of the relation between electricity and magnetism and studies of the atomic nucleus, looking ultimately toward the enunciation of the laws of interaction of electrons, protons and radiation, for very close distances and high energies, is briefly indicated. Maxwell's equations are a first approximation for macroscopic distances and low energies; the quantum mechanics constitutes a second approximation, which holds fairly well for atomic distances and intermediate energies; the third approximation required for nuclear dimensions and energies has not yet been obtained.

To extend the scope of the experiments which have been carried out using radioactive sources, an effort has been made to develop an artificial laboratory-source of high-energy particles and radiations. Measurements of the peak-voltages produced by oil-immersed Tesla coils showed that potentials up to several million volts were readily obtainable in this way. Using this inexpensive source, experiments were carried out on the development of vacuum-tubes to withstand such voltages, resulting in the successful application of voltages as high as 1800 kilovolts (limited by size of oil-tank) to

cascade-type tubes based on Coolidge's design. Magnetic deflection-measurements were carried out on the high-speed electrons from such tubes, which verified the capacity-potentiometer measurements of voltage. Rough measurements showed the expected hard components (gamma-rays) to be present in the radiation from a target bombarded by these fast electrons. Observations by magnetic analysis of ions, which were evidently high-speed protons, produced by a flashing tube, were entirely confirmed by unambiguous analysis into Thomson parabolas by magnetic and electric deflection. Tracks produced by such high-speed protons in a Wilson cloud-chamber were obtained and photographed, and a rough measurement of the range of 1000-kilovolt protons was carried out. The result showed that the beta-ray law (velocity to the fourth power) can not be true for these proton-ranges, and indicated that the range of 1000-kilovolt protons is near to that predicted by the alpha-particle law (velocity cubed). A brief indication is given of some of the developments at present in hand or under way.

The geophysical significance of radio measurements of the ionized layer. M. A. Tuve. Nat. Res. Council, Trans. Amer. Geophys. Union, 13th annual meeting, 160-166 (June 1932). [Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 28, 1932.]

Geophysical data may be classified in two groups, namely, data from *physical analysis* and data from *statistical analysis*. Physical analysis can establish the existence of a geophysical condition or entity. Statistical analysis can establish relations between geophysical variables. This paper on radio measurements of the ionized layer in the upper atmosphere is divided accordingly.

Reviewing the basis of the physical analysis of the problem under discussion, the five methods which have been developed to date for obtaining radio measurements on the ionized layer are outlined. Particular attention is given to the echo-method and the extent of the physical data which ultimately may be obtained by its use. Attention is called to the basic difficulty, a discontinuity in the value of the "optical path" due to the decrease in ionization above the lower stratum of the layer ("*E*-region") which stands in the way of efforts to calculate true heights of the higher stratum ("*F*-region") from the observed values of the equivalent heights.

Consideration of the statistical phase of the problem, namely, of the relations which may be established between variations in the ionized layer and other geophysical phenomena, is almost entirely restricted in this paper to an emphasis on the necessity for applying to such data and conclusions the proper tests of their validity as statistical deductions, and to a presentation of examples of such tests as applied to magnetic data by the author's colleague, Dr. J. Bartels. Proof of such validity can only come from the data themselves. The primary necessity for data covering more than one cycle before any conclusions are drawn as to correlations of a given period is first emphasized, especially by showing the marked fluctuations in the correlation of closely connected geophysical variables. The importance of "after effect" in statistical problems is indicated. Two tests of primary importance are given. The first is a test for the reality of a harmonic component obtained when a given set of data is subjected to a Fourier analysis. To analyze a given set of data and find that a chosen harmonic component is present with a certain amplitude and phase has *no significance whatsoever*. Any arbitrary array of numbers different from each other will

give such "periods." The "harmonic-dial test" of Dr. Bartels obtains a quantitative criterion for the reality of a period found, for example, in a mean of  $N$ -years, from the statistical fluctuation of the same period in the data for each of the  $N$ -years. Thus any conclusions as to supposed periods in geophysical data must be supported by such internal statistical evidence from the data themselves. The second test is not restricted to sine-waves (harmonic components), and consists essentially in determining whether the variations decrease with  $\sqrt{N}$ , as the number  $N$  of observations increases. Variations which do not decrease in this way are due to causes other than statistical fluctuations. This constitutes a test for the reality of an average recurrent variation.

High-speed protons. M. A. Tuve, L. R. Hafstad and O. Dahl. *Phys. Rev.*, vol. 39, 384-385 (January 15, 1932).

High-speed protons from a vacuum-tube used with a Tesla coil as reported at the 1931 Pasadena meeting were passed into a Wilson expansion-chamber through a thin mica window and photographs of the tracks were obtained. By magnetic analysis all particles except a definite group of protons with velocities falling in a small interval were excluded. The relation between the velocity of the particles (given by the  $H\rho$  value for which the magnetic analyzer is set) and the range of the particle in air could then be directly obtained.

It is known that the range of fast alpha-particles (charge 2, mass 4) varies as the cube of the velocity and that the range of a beta-particle of the same energy (hence much greater velocity) varies as the fourth power. The above measurements exclude the beta-ray law and show that law for protons (charge 1, mass 1) is nearer to the third-power law which obtains for alpha-particles.

Note on the establishment of observatories for the measurement of atmospheric electricity. G. R. Wait. C. R. Assemblée de Stockholm, août 1930. *Union Geod. Geophys. Internat.*, Sec. Mag. Electr. Terr., Bull. No. 8, 346-347 (1931).

Aitken condensation-nuclei and atmospheric potential-gradient at Washington, D. C. G. R. Wait. C. R. Assemblée de Stockholm, août 1930. *Union Geod. Geophys. Internat.* Sec. Mag. Electr. Terr., Bull. No. 8, 349-350 (1931).

The Aitken pocket nuclei-counter. G. R. Wait.

Many investigators in recent years have made use of measurements obtained with the nuclei-counter devised by Aitken, in studies of atmospheric pollution and in the correlation of this phenomenon with atmospheric electricity. For a precise determination of the number of nuclei per cubic centimeter, one requires not only a properly working instrument and the making of accurate counts, but also the application of correct instrumental constants. Considerable disagreement seems to exist among the users of this instrument, as to the proper basis for determining instrumental constants. Satisfactory directions have never been published for obtaining these constants from dimensional measurements. The possibility of misinterpreting Aitken's instructions for calculating the number of nuclei in the outside air from data obtained with his instrument, together with the fact that no adequate instructions exist for determining Aitken nuclei-counter constants from instrumental measurements, has led the author to present these instructions.

Data have been obtained in an experiment designed to furnish information as to whether or not some of the water-drops formed around nuclei in



the pump-chamber may evaporate, leaving some nuclei free to return to the receiver on the up-stroke of the piston, to account for the deposition on subsequent rarefactions. It has also been possible to determine, from the results of this experiment, whether the same percentage of nuclei falls inside the pump-chamber as inside the receiver. The results show that the nuclei falling on expansions subsequent to the first are not due to their being returned after evaporation inside the pump-chamber. These results also show that while the same percentage of nuclei does not fall inside the pump-chamber as inside the receiver, yet only a small error will be introduced by making such an assumption. One is now able to say, as a result of experiment, that in making a nuclei-count with an Aitken pocket nuclei-counter, those falling on the subsequent as well as the first rarefaction should be counted. One is justified also in saying, in view of the experimental results, that the instrumental constant obtained in accordance with the equation developed in the paper will not be in error by more than a few per cent.

Rate of ionization of the atmosphere. G. R. Wait and O. W. Torreson. *Nature*, vol. 129, 401-402 (March 12, 1932.)

Quelques facteurs affectant la conductibilité électrique de l'atmosphère. G. R. Wait and O. W. Torreson. *Cong. Internat. d'Electricité*, Paris, 11<sup>e</sup> Section, Comm. No. 5-C, 10 pp. (1932). [Prepared for International Electrical Congress, Paris, July 1932.]

The electrical conductivity of the atmosphere varies from place to place and systematically through the day and through the year. The chief cause of the variations is the alteration in the number of small ions present. Large ions and condensation-nuclei act to remove the small ions and the latter are at the same time replenished by radioactive emanation and matter. The efficiency with which the large ions and nuclei remove the small ions depends upon the ratio of the one to the other present in the atmosphere, upon the electronic charge per ion, and upon the capability of the nuclei for becoming large ions. From study of the removal of the small ions under equilibrium conditions, it is possible to secure information also about the replenishment conditions.

An apparatus for the measurement of large ions has been built by the Department and used during the past year together with a small-ion counter. Measurements are made simultaneously with both instruments on the same sample of air. Measurements of the number of charged and uncharged Aitken nuclei are also obtained by observation on the air just as it enters and just as it leaves the ion-counters. Some of the results obtained are as follows: (1) The electronic charge on the large ion in the free atmosphere is one; (2) all Aitken condensation-nuclei are capable of becoming large ions; (3) all large ions can act as Aitken condensation-nuclei; (4) at Washington, D. C., 70 per cent of the Aitken condensation-nuclei are uncharged and the remaining 30 per cent are charged about equally positively and negatively; (5) the value of the recombination-coefficient between small ions and large ions of opposite sign is five times the value of the coefficient for small ions and uncharged nuclei; (6) the value of the recombination-coefficient for small ions and Aitken nuclei was found to be  $1.8 \times 10^{-6}$ ; (7) the calculated rate of ionization,  $q$ , for Washington, D. C., shows a definite diurnal variation; and (8) the calculated value of  $q$  for Washington, D. C., is only about 25 per cent of that found at most localities from radioactive measurements.



- Slow-moving ions in the atmosphere. G. R. Wait and O. W. Torreson. Nat. Res. Council, Trans. Amer. Geophys. Union, 13th annual meeting, 182-187 (June 1932). [Presented at the meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, April 28, 1932.]
- The number of Langevin ions in the free atmosphere at Washington, D. C. G. R. Wait and O. W. Torreson. (Abstract) Phys. Rev., vol. 40, 1046 (June 15, 1932). [Presented before American Physical Society, Washington, D. C., April 1932.]
- The geographical distribution of magnetic disturbance. W. F. Wallis. C. R. Assemblée de Stockholm, août 1930. Union Geod. Geophys. Internat., Sec. Mag. Electr. Terr., Bull. No. 8, 270-272 (1931).
- The geographical distribution of magnetic disturbances. W. F. Wallis. (Abstract) Jour. Wash. Acad. Sci., vol. 22, 278 (May 19, 1932).
- A note upon vertical intensity at the Apia Observatory. C. J. Westland. Terr. Mag., vol. 37, 177-178 (June 1932).



## TORTUGAS LABORATORY<sup>1</sup>

W. H. LONGLEY, EXECUTIVE OFFICER

The Laboratory was open from June 1 to August 21, 1932, during which time the following investigators worked for the periods and upon the problems indicated.

- Paul Bartsch. U. S. National Museum. Cerion hybridization. August 10 to 21.
- A. A. Boyden. Rutgers University. Serological study of invertebrate relationships. June 1 to July 25.
- L. R. Cary. Princeton University. Invertebrate tissue culture. July 27 to August 21.
- M. W. de Laubenfels. Pasadena Junior College. Physiology and taxonomy of sponges. June 15 to August 8.
- F. R. Hayes. Dalhousie University. Nitrogen in early echinoid ontogeny. June 1 to August 8.
- James L. Leitch. University of California. Water exchange of cells. June 1 to July 11.
- Warren R. Lewis. Johns Hopkins University. The effect of selected indophenol dyes on fishes. June 15 to July 25.
- W. H. Longley. Goucher College. The habits and distribution of fishes. June 1 to August 21.
- H. W. Manter. University of Nebraska. Taxonomy and life-histories of trematoda. June 15 to August 8.
- Waldo L. Schmitt. U. S. National Museum. The bathymetric distribution of decapod crustacea. June 15 to August 8.
- R. G. Stone. University of Missouri. The effect of radium radiation on regeneration in *Euratella*. June 1 to August 8.
- John W. Wells. Cornell University. Reef corals. June 15 to August 8.
- O. L. Williams. University of California. Nematode parasites of fishes. June 1 to August 8.
- Shigeo Yamanouchi. University of Chicago. Life-histories of algæ. June 1 to July 11.

During the season authorized repairs were made upon laboratory buildings. Earlier the launch *Velella* was rebuilt as contemplated, again giving the Laboratory two serviceable boats of intermediate size for routine work of collecting or for transferring working parties from key to key within the group. The addition of 500 fathoms to the cable used in dredging from the *Anton Dohrn* makes it possible to operate in 600 fathoms, which is as great depth as she may explore while retaining Tortugas as her base.

For details concerning the scientific work of the season, the reader is referred to investigators' individual reports, to which the following may serve as an introduction.

Dr. Bartsch has increased his plantings of cerions in mixed colonies with the idea of facilitating their crossing and increasing the material available for studying its effects. The work is of especial value in connection with his own studies of the local distribution and evolution of terrestrial mollusca of Cuba, other West Indian islands and the Philippines.

<sup>1</sup> Located at Tortugas, Florida.

Accepting the fact of evolution, and without immediate interest in its mode, Dr. Boyden attempts by serological methods to determine the closeness of the relationship between some of the invertebrate types to which it has given rise. Some of the species with which he is working are of uncertain affinity and his findings may be awaited with interest.

The researches of Doctors Cary, de Laubenfels, Hayes, Leitch and Stone and Mr. Lewis directly or indirectly deal with problems of growth and differentiation.

Dr. Cary has so far been largely and successfully engaged in developing methods of tissue culture readily adapted to use in the ordinary marine laboratory. It is to be hoped he may next apply them in study of problems presented attractively by marine invertebrates.

Dr. Stone, who by courtesy of the National Research Council's Committee on Radiation has enjoyed the use of radium, has brought to successful conclusion a study continued through two seasons. He finds that the beta rays are chiefly responsible for the diminished powers of regeneration displayed by the tissues of irradiated worms in his experimental cultures.

Mr. Lewis's attempt to discover the effect upon pigmented dermal cells of fishes of certain dyes known to decolorize similar cells in living tadpoles has perhaps failed for the moment, at least, on account of their failure to be absorbed. A modification of procedure may perhaps eventually open the way for profitable investigation of the pigmented, cancerous growths of fishes from this new direction.

Dr. Manter's study of the trematode fauna of Tortugas, in collection of material for which he has enjoyed the assistance of Dr. O. L. Williams during the season, has progressed notably. His data promise to have much value not only as a contribution to systematic knowledge of a group of animals with respect to which much remains to be learned, but to lend themselves to use in a connection mentioned in last year's report. This phase of his research dealing with geographical distribution is part of a joint investigation in which Dr. Schmitt and Dr. Longley participate.

#### *Cerion Breeding, by Paul Bartsch*

This year's efforts were centered about two problems: First, an examination of the existing colonies at the Tortugas, particularly the status of that of the first generation of hybrids between *Cerion incanum* and *Cerion viaregis* reported upon last year. Only five of the eight have survived. Secondly, the establishing of new mixed colonies of *Cerion incanum* and *C. viaregis*; and *Cerion incanum* and *C. casablancae*. Two such colonies, consisting of 500 of each species, were planted.

One of these, *Cerion incanum* and *C. viaregis*, is placed on the south end of Loggerhead Key, the place being marked by a stake bearing a metal plate with proper legend. Another mixed colony of the same combination has been planted on the southwest corner of Garden Key outside of the Fort.

Of *Cerion incanum* and *C. casablancae* a mixed colony of 500 each was planted near the pump house on the north side of the laboratory on Loggerhead Key, and another of an equal number on the northwest elevated reach of Long Key.

From these new colonies it is hoped to get sufficient first generation hybrids from which we may obtain the second generation of progeny.



The second combination was made desirable because we found this crossing to have taken place on Bahia Honda Key last year. The status of the free colonies living on the various keys is satisfactory.

#### THE BIRD ROOKERIES OF THE TORTUGAS

The usual breeding colonies of sooties, noddies, common, roseate and least terns were present in the quarters previously occupied, but several decided changes in these tern colonies are to be recorded, namely, that about twenty pairs of the least terns were breeding on the hook at the north end of Loggerhead Key this year. By far the most interesting development in these tern colonies centers this year about Bird Key, which has again suffered a decided diminution from wind and weather with the result that it scarcely offers adequate quarters for the large number of birds that it has been harboring, and this has resulted in the first attempt at an exodus so far recorded.

About 100 nests, probably 70 of the noddy and 30 of the sooty, were found on the elevated portion of Bush Key in an exceedingly retarded condition of development, some still containing eggs, others newly hatched young and the most highly advanced being less than half-grown at the end of our laboratory season, while on Bird Key almost all the birds were on wing. The noddies of this colony occupied the pads of *Sesuvium*, and the sooties, as usual, the intermediate stretches of sand. This is a very unfortunate selection for the first real stormy sea is sure to wash over the place. A better selection is that of another group of noddies, who have made about 32 nests in the few tall bay cedars at the western end of Long Key.

A third unfortunate choice was made by another small group of noddies who selected the tops of groups of massed piles on the south side of the east dock of Fort Jefferson on Garden Key. The young raised here when old enough to move about, some half-grown, had evidently fallen overboard and been lost.

This restlessness on the part of the Bird Key tern colony is more than interesting, and it should be remembered that the sooties and noddies breed nowhere else in the United States. The logical key that should be selected by them is Loggerhead Key whose bay cedars and sandy reaches would furnish an ideal habitat for these birds, but here they would prove a decided nuisance to both our laboratory and lighthouse people, both of which are dependent upon rain water and cisterns for their water supply, which the droppings of these birds would render impossible.

#### PHOTOGRAPHS

Time and weather permitting, 1300 feet of moving picture film were exposed: 300 showing the present status of the bird rookeries on Bird Key and the new sites chosen by the terns, and 1000 feet undersea about the Coral Reef.

#### *Serological Study of the Relationships of some Common Invertebrata, by Alan Boyden*

The precipitin reaction, known to possess certain advantages over other methods of studying systematic relationships, has heretofore been applied chiefly to the investigation of relationships within the Vertebrata. The heterogeneous assemblage of Invertebrata, whose interrelationships are much less certain, has scarcely been touched. The collection of materials to serve as antigens in such an investigation was begun at Tortugas.

The method of antigen preparation includes the following steps: (1) Collecting and starving the animals; (2) obtaining the body fluids (where present) and grinding the tissues with the addition of sterile salt solution; (3) vigorously shaking the ground tissues in a shaking machine; (4) filtering the extracts, ending with a final sterilizing filtration through Seitz filters; (5) storing in sterile condition in 5 ml. serum vials; and (6) testing for sterility and protein concentrations.

In some cases the extracts were concentrated by blowing with electric fans before the final filtration.

What appear to be satisfactory antigens for use in the production of antisera, were obtained for 28 genera distributed as follows: Porifera, 2; Cœlenterata, 1; Sipunculoidea, 1; Annelida, 3; Crustacea, 5; Mollusca, 7; Echinodermata, 6; Prochordata, 3.

In addition, other antigens representing seven more genera were obtained which will be suitable for titration, even though not concentrated enough for injection. They are distributed as follows: Cœlenterata, 4; Mollusca, 1; Echinodermata, 1; Prochordata, 1.

Finally, samples of the blood sera of three of the lower Vertebrata were obtained, to be used in the study of Prochordate affinities.

The next step in the investigation will be the production of the precipitating antisera and this will be followed by the making of the actual titrations by means of which further light may be thrown on the systematic relationships of the species studied. The results should help to make more clear the proper location of those species of "uncertain systematic position," and to make more quantitative the expression of the interrelationships of all the forms studied.

#### *Report on Tissue Culture, by L. R. Cary*

My work during this season was confined to a study of the behavior *in vitro* of tissues of *Ptychodera bahamensis*. The routine procedure for making the cultures, described in my report of last year, gave uniform success.

Sterilization of tissue fragments by irradiation with ultra-violet from a mercury vapor-bulb was equally efficient. This procedure resulted in a marked saving of time. There was no apparent deleterious effect on the tissues from an exposure of  $2\frac{1}{2}$  minutes at 15 cm. All bacteria were destroyed or rendered incapable of reproduction for several days. After a week, bacterial activity sometimes became very marked in cultures prepared by this procedure. A peptic digest of entire *Ptychodera*s was used as a nutrient medium in the preparation of all cultures.

Last season almost complete failure resulted in attempts to obtain satisfactorily stained preparations from the cultures, as a permanent record of their activities. Consequently an extensive series of photomicrographs of cultures throughout the period of their development was made during the first two weeks of this season. Later a series of micro-cinematographs of the growth of explants from the digestive cœca were taken.

The structure of *Ptychodera* makes it possible to choose as an explant a small fragment of tissue from the dorsal side of the mid-section of the body which will contain: (1) The ectodermal epithelium; (2) nerve cell; (3) cells from the digestive (hepatic) cœca; (4) muscle cells; and (5) connective tissue cells. In a culture from such an explant the first visible growth is that of nerve fibers. Then endoderm cells from the cœcum begin to migrate as flask-shaped bodies. Their stalks become very long and

slender. Before these primary migrants have separated from the explant, other cells, to which the former are attached, move out from the mass of tissue. This process continues until often a chain of ten or more endoderm cells extends out from the explant. In the meantime many muscle cells become separated from the tissue mass. Their behavior varies greatly. Some become greatly elongated and show marked amœboid activity. Others shorten to masses of rectilinear shape. These soon swell until a clear vacuole surrounds the central mass of protoplasm. Later these may elongate and become extremely active.

By the time the greatest activity of the above-mentioned cells has been passed, a mass migration of the ectodermal epithelial cells takes place. This has the appearance simply of a flowing of the cell mass. Soon the other types of cells are entirely overgrown and hidden by the migrating ectoderm cells. The culture now appears as a smooth mass of rounded cells and all evidence of earlier activity of other elements is lost.

When an explant is selected which consists of cæcal endoderm alone, migration continues until no central mass is distinguishable. The component cells of the culture move about actively over the cover-slip. The protoplasmic strands between cells become highly attenuated. Relatively large areas are seen where only these connecting strands are to be found.

At the time of the division of the cells, their characteristic pigment granules may be passed on entirely to one daughter cell. The other now appears as a clear mass of protoplasm. When freed in this manner from the large granules, the cells exhibit unusual amœboid activity. They lose their characteristic shape and can not easily be distinguished as descendants of their parent cells.

Subcultures were easily obtained from many slides. When a fragment of the original explant was used, activity was always very marked. Indeed, subcultures from slides on which there had been no growth were usually very active as though the explant had been released from some inhibiting influence operating in the original culture.

Subcultures containing pure cæcal endoderm cells were easily obtained and kept alive for a period of two weeks without transfer. When transfers were made every 48 hours, these cultures could be carried on indefinitely.

#### *Studies Upon Tortugas Sponges, by M. W. de Laubenfels*

In continuation of my work on sponges at Tortugas, particularly with reference to methods of regeneration, cylindrical species were cut transversely and kept under observation while the injury was repaired. Sometimes disks were cut from such sponges, kept between glass, and watched while the new surface was formed, in this case not across the wound but out to the glass. Active moving about of cells in and from the sponge was involved, and some metamorphosis of one cell sort into another.

The commercial sponge *Spongia officinalis* (Linné) was more abundant this year than earlier, but was unsuited for experimental work with dissociated cells, because its cells refused to come out of suspension even when centrifuged.

A few observations were made upon sponges eaten by fishes under normal conditions, and upon the effect of feeding suspensions of sponge cells to others.

The specific descriptions of sponges by early students of the West Indian fauna are often so brief as to be worthless. There are excellent recent papers, but the number of species of which they treat is not large, and



very real need for additional systematic study of the group still exists. It seemed good, therefore, to undertake it now, since the season's dredging for other purposes yielded incidentally an abundance of sponges from depths ranging from 15 to more than 1000 m.

The dredged specimens were often studied while still alive and usually before post mortem changes had set in. There numbers were supplemented by material collected with sponge-hook or diving-hood, or by hand from the reef at low tide. Over 80 species in all were obtained. Examples of each, preserved in alcohol, are being deposited in the U. S. National Museum, accompanied in many instances by representative series of dry specimens. Microscopic preparations of each were also made, with descriptive notes, and notes upon the ecology of the species where possible.

*Nitrogen in Echinoid Ontogeny, by Frederick Ronald Hayes*

After the penetration of a spermatozoon, the developing egg receives nothing from the outside except water and sometimes salts, until the comparatively advanced embryo begins to eat. The morphological phenomena of ontogeny—intra-cellular reorganization, cell division, gross changes in size and shape—can be brought about only by the expenditure of energy, and this energy must come from materials in the egg at the time of fertilization. The problems of chemical embryology include (a) a determination of the amount of energy required to produce these structural changes—the overhead expenses of development; and (b) an investigation of the chemical transformations taking place. Using sea-urchin eggs as material, the former problem received attention some years ago from Warburg and others. Oxygen requirements, carbon dioxide output, and heat production at various stages, suggested that the same material was not being burned to provide energy at all times. Virtually nothing has been done, however, which throws light on the chemical changes during invertebrate egg development. This therefore seemed a suitable field for a preliminary investigation at Tortugas, with the sea-urchin (*Echinometra lucunter*) as material.

There are two sources of energy available in the egg—proteins and lipins. (Probably the very small quantities of carbohydrate present can be neglected.) In the time available, an attempt to make a general survey of the changes in these two classes of material would necessarily have been unsatisfactory. It was therefore decided so to limit the scope of the work that a clear-cut result might be anticipated.

Primary amino groups were found to account for nearly 40 per cent of the nitrogen in *Echinometra* eggs. Now  $-\text{NH}_2$  nitrogen is known to change in many metabolic processes, particularly with respect to its relation to  $=\text{NH}$  and  $\equiv\text{N}$  nitrogen. A study of the variation in the ratio  $\frac{-\text{NH}_2 \text{ nitrogen}}{\text{total nitrogen}}$  during the first 24 hours of development was made, for the purpose of gaining some idea whether profound protein transformations accompany cleavage, hatching and gastrulation. Koch's modification of van Slyke's micro-apparatus was used for the estimation of  $-\text{NH}_2$  groups; and micro Kjeldahl tests were made for total nitrogen. The results showed that, although there may be small variations, no major change occurs in the ratio investigated. From this it may be suspected that there is probably little change in the protein during the early stages, although a quantitative estimation of the several amino acids present would be necessary before a definite conclusion could be reached. It might be further



reasoned that since chemical changes of some sort almost certainly form a part of development, it would be profitable to make a study of the lipins.

Some preliminary observations were made of the size changes during the first 24 hours. Measurements of diameters showed that the egg within the shell (or fertilization membrane) decreased in size until hatching time (6 to 7 hours), following which there was a period of rapid growth. The diameter of an egg is 85 to 90 $\mu$ . Progress was made toward the elaboration of a method by which these small eggs may be weighed. Weighing is more desirable than diameter measurement for purposes of volume estimation, because with the latter method one must assume that eggs are spherical, which is not usually true.

*Water Exchanges of Cells, by James L. Leitch*

The object of the summer's work was to study the whole process of water exchange between ova of suitable types, particularly those of several echinoderms, and hypo- and hypertonic sea-water solutions. The program included the collection of samples for subsequent analysis and the measurement of the diameter of the eggs placed in anisotonic sea-water solutions. These measurements were made either by means of a filar ocular micrometer or by photographing the eggs and measuring the negatives. In all, some 320 photographs were taken which will be measured and the resulting data calculated during the coming year.

The ova of *Tripneustes esculentus*, *Lytechinus variegatus* and *Centrechinus antillarum* were not found in sufficient abundance or in proper condition for use.

The eggs of *Echinometra lucunter*, which was obtained in great number from Bird Key Reef, were used in the majority of the experiments. The eggs were obtained free from contamination by sperm or fluids from the coelom or digestive tract by washing the animals in tap-water and then inverting them in a dish of sea-water. The animals spawned within 15 minutes. Photographic records of the volume changes when eggs were transferred from 100 per cent sea-water to 50 per cent and vice versa were made. From these photographs, studies will be made of: (1) The kinetics of the process of water exchanges; (2) the non-solvent volume of the eggs; (3) the effect on the non-solvent volume of keeping the eggs for 40 hours in the ice box; and (4) the variations in the kinetics of the volume changes for different samples of eggs from the same female and for samples of eggs from different females.

In addition to the photographic records, samples of eggs from each female used in the above experiments were thoroughly washed with filtered sea-water and prepared for analysis after the removal of most of the sea-water by centrifuging. Samples of the eggs of 40 females were also prepared in this manner for the determination of the variability in their chemical composition.

In preparation for future study of the reactions of eggs of animals of other phyla to hypo- and hypertonic sea-water solutions, a series of 56 pairs of samples of the eggs of individual female hermit crabs, *Calcinus tibicens*, were prepared. Each pair of samples consisted of a few eggs placed in Bouin's solution for a study of the shape of eggs at various stages in development, and a much larger sample for analytical study. The latter was prepared by washing the bunches of eggs in two changes of distilled water and then placing them in small vials in which they were dehydrated at 100° to 110° C. In the same manner, paired samples were made of the

eggs from one female of *Panulirus argus*, 4 of *Acanthocarpus alexandri*, 1 of *Stenocinops spinosissima*, 3 of *Portunus spinicarpus*, and 9 of *Mithrax verrucosus*.

*Effects of Selected Indophenol Dyes on Fishes, by Warren Reed Lewis*

Tadpoles which develop in solutions of certain of the phenol indophenol dyes lose the pigment from the skin and also from the eyes (M. R. Lewis). Therefore it was thought interesting to see whether these dyes could bring about a similar destruction of the pigment of other types of animals, particularly of the marine fishes.

Investigations were undertaken at the Tortugas Laboratory in collaboration with Mr. W. R. Kenny who prepared a number of dyes with these experiments in view. The dyes used were o-chlor phenol indophenol, phenol indophenol, both the Na salt and the free acid forms, and 1 naphthol 2 sulphonate indophenol which give a range of reduction potential from +0.233 to +0.123. The concentrations used were 1:100,000 and 1:200,000. Members from 4 families of fish were used: *Halichæres bivittatus* (Bloch), *Bathygobius soporator* (Cuvier and Valenciennes), *Malacoctenus moorei* (Evermann and Marsh), *Pomacentrus analis* (Poey).

No changes were observed in the living fish after four weeks, even though the concentrations of the dyes used in these experiments were much stronger than those used in the experiments on developing tadpoles.

The results seem to indicate that the dye did not penetrate the skin. However, in order to determine this, the preserved materials will be prepared in sections for microscopical observation, and in addition some of the sections will be oxidized to show whether any of the dyes may have passed through the epidermis in a reduced form.

A few types of invertebrates were tried but none survived under the conditions of the experiments.

*Observations Upon Tortugas Fishes, by W. H. Longley*

Chiefly as an incidental result of dredging undertaken for other purposes, several species have been added as usual to the local fish fauna as a result of the summer's work. There has not yet been opportunity to identify all precisely. The list includes at least these: *Antennarius* spp., *Chaetodon aya*, *Cryptotomus roseus*, *Epinephelus niveatus*, *Gillellus* sp., *Gymnachirus fasciatus*, *Porichthys porissimus* and *Scorpaena inermis*.

Information has also been obtained upon a matter which attracted attention a year ago. Specimens of *Prionodes phæbe* and two other unnamed species of the genus, to the number of 40 in all, collected at different times and places, were without exception apparent females. Actually, it appears now, all three species are normally hermaphroditic. Active sperm cells in abundance have been taken from fishes of the two unnamed species whose eggs were at the same time almost ripe. Specimens of *P. phæbe* examined were not so nearly sexually mature and gave a less satisfactory demonstration of its bisexuality. It is to be anticipated, however, that the hermaphroditic condition prevails widely in the genus, for 11 mature specimens, distributed among four other species which there has been opportunity to examine, are also to superficial examination females only. None has a normal testis.

Actually the condition is by no means confined to the genus *Prionodes*. *Diplectrum bivittatum*—a species perfectly distinct from *D. radiale*, with which it has been confused—is also a functional hermaphrodite from which

I have had living sperm cells, together with eggs almost or quite mature. *Diplectrum formosum* is not mature at Tortugas at the end of August, but its immature gonads are all of one type, resembling immature ovaries. Four sexually mature museum specimens contained eggs, and one examined closely showed between the lobes of the gonad and behind the point of their union on the ventral side just such a mass of tissue as in *D. radiale*, and, in the species of *Prionodes* in life, yields sperm.

*Hypoplectrus* is another genus which, with little doubt, will prove to be like these in its mode of reproduction. I have seen 17 ovigerous museum specimens but no definitive males. Again the gonad of a specimen closely examined showed proximally on the ventral side a region resembling that from which the sperms of the other hermaphrodites come. In two of Poey's types in the Museum of Comparative Zoology this apparent spermatogenous tissue extends distinctly upon the lateral face of the gonad.

*Dules auriga* with 8 ovigerous specimens but none with normal testes promises to be another of the same sort. In any case, these observations with those of others show that normal hermaphroditism occurs very commonly among the lesser Serranidae, though the conclusion does not apply to the genus *Pronotogrammus*.

A part of the summer was devoted to study of the bathymetric distribution of fishes within the 600-fathom line, but much the greater portion was spent in checking and organizing for publication data regarding species known from within the 100-fathom line. A note upon progress made will be found elsewhere in this volume.

*Continued Studies on Trematodes of Tortugas, by H. W. Manter*

Examination of fishes of Tortugas for helminth parasites has been continued another summer, this season with the assistance of Dr. O. L. Williams. Approximately 2400 fishes including 272 species have now been examined, almost all of them individually. Of the species of fishes, 80 per cent are subject to trematode infection. About 60 additional species of trematodes were added to the Tortugas list during the summer, bringing the total number to over 210 species from fishes alone. Of these, approximately 33 are monogenea. A large number of the fishes were secured by trawling at varying depths down to and including 582 fathoms. At all these depths the fishes were found to be more or less infected with trematodes and the indication is that the fairly deep ocean is well populated with these parasites.

Many new host records were secured. These, it is hoped, will contribute to correct understanding of specificity and distribution within this group of parasites. Knowledge of bathymetric distribution of certain trematodes is also growing. It is clear that there are rather definite vertical limits varying with the species. Most of the deeper-water forms belong to different species than those found near the surface, and enough collections have been made to give considerable significance to the upper and lower limits of occurrence.

Among the few species of trematodes of Tortugas also occurring north to Woods Hole is the form described from Beaufort by the author as *Rhagorchis odhneri* Manter 1931 (Parasitology, vol. 23, pp. 405-406). This species is, in reality, the same as the *Distomum pallens* Rud. of Linton 1898 (Proc. U. S. Nat. Mus., vol. 20, p. 526) and the correct name for the species depends on the confirmation of identity with Rudolphi's form.

The distribution of *Distomum fenestratum* at Tortugas is exceedingly wide. The parasite occurs, always in juvenile form, in many (at least



22) widely different hosts, including some from 168 fathoms as well as from shallow-water fishes. A massive infection in a ray (*Pteroplatea maculura*) from 60 fathoms shows that very heavy infections may occur in nature. There are probably at least two other species at Tortugas related to *Distomum fenestratum* but with much smaller ventral suckers. The Cercaria L of Miller 1925 (Carnegie Inst. Wash. Year Book No. 24, p. 238) from *Crepidula aculeata* seems to resemble this species of trematode very much since the large vesicles or swollen regions of the ceca are characteristic. It is possible that the sexually mature adults are to be looked for among the Didymozoonidæ.

The life cycle of *Helicometrina nimia* (Linton) was discovered in part. The metacercariæ are very commonly encysted in the thoracic region of *Lysmata intermedia* (Kingsley), a shrimp common among the *Porites* coral. The larvæ also occur, although less commonly, in the snapping shrimp, *Crangon formosum*. The adult trematode occurs in at least thirteen species of fishes. The fully developed metacercaria is recognized by the nine testes. The only other known *Helicometrina* (a new species) constantly has but five testes. Immature forms of *H. nimia* from fishes are indistinguishable from the metacercariæ from the shrimps. The cercaria of *H. nimia* is very possibly Cercaria J of Miller 1925 (Carnegie Inst. Wash. Year Book No. 24, p. 237) from *Columbella mercatoria*. At least, these cercariæ readily encyst in *Lysmata intermedia*. An overdose of the cercariæ proved fatal to four shrimps within a few hours. The cercariæ agree in all respects with *H. nimia* except in position of the pharynx.

Another partial life history became fairly apparent with the discovery that a Lepocreadid metacercarian very common as a free inhabitant (un-encysted) in the intestine of many fishes of depths from 40 to 60 fathoms agreed in every respect with a species of *Lepidapedon* found in the intestine of *Epinephelus niveatus*. The very general occurrence, the sharply limited depth distribution, and the fact that the metacercarian is an unencysted, juvenile form make this life history of especial interest.

From the loggerhead turtle were secured several new records of trematodes of that host in America. These include the Aspidogastrid, *Lophotaspis vallei*. Eggs of this trematode were found to hatch readily. The miracidium is elongate-oval in shape, varying, according to contraction, from 150 to 210  $\mu$  in length. There is a large sucker at the posterior end. Two eye-spots, close together, occur dorsally about one-third from the anterior end. The long cilia are limited to three ciliated plates, one at the extreme posterior tip behind the posterior sucker, the other two lateral just behind mid-body. The plates appear as transparent low elevations, 20  $\mu$  in length. There is an elongate oral sucker at the anterior end, and an oval pharynx near the level of the eye-spots. No flame cells could be seen. The miracidium swims rapidly by means of its cilia, or it can creep into an inch-worm, extending its anterior end, releasing its posterior sucker, then pulling the posterior end up near the mouth. Five different cases of abnormal hatchings were watched in which the miracidium was reversed in the egg shell so that the posterior sucker emerged first. Such hatchings were difficult and often abortive or incomplete.

#### *Crustacea of the Tortugas Region, by Waldo L. Schmitt*

The general survey of the crustacean fauna which has been carried on during the past several seasons, has just about been brought to a conclusion with the investigations conducted this year. The additional and



improved equipment provided on the *Anton Dohrn* rendered it possible to carry vertical observations down to nearly 600 fathoms—a depth far exceeding any haul yet attempted by the laboratory and a record for the *Dohrn*.

Of more than a dozen successful hauls this season from 100 fathoms or more, not less than six were made at depths between 290 and 580 fathoms. These have furnished extensive data bearing on a zone or zones not hitherto examined by us. It would seem that the bathymetric zonation of the deeper-water crustacea, foreshadowed last year, may be even more significantly indicated when the studies upon the materials secured will have been completed.

Noteworthy among the rarer forms obtained were several specimens of the Calappid crab, *Acanthocarpus bispinosus*, first described in 1880 by A. Milne Edwards from a single specimen taken by the *Blake* off the Grenadines in 140 fathoms, and so far as I am aware not again seen in the intervening half century. The Tortugas specimens are from 135 to 168 fathoms, south of Loggerhead Key. It may here be noted that this species and the only other known member of the genus, *A. alexandri* Stimpson, which has been so abundantly represented in the *Dohrn* dredgings between 60 and 110 fathoms, are both stridulating crabs. This fact seems to have passed unnoticed, though the vertical flattened file of finely cut, close set, oblique ridges on the inner face of the palm and the suborbital row of sloping, "dash"-like tubercles on the carapace against which they play are quite prominent structural features in these species. When touched or taken in the fingers under water, the crab may set up such a strong vibratory grating that the fingers are literally made to tingle.

Considerable new information regarding the food of Tortugas fishes was derived from the stomach contents of a number of species not examined in past years. Of particular interest among the crustacean records so established was the discovery of a small Pandalid shrimp in the stomach of a flounder, *Trichopsetta ventralis* Goode and Bean, from 70 fathoms. Though differing markedly in rostral armature, it is very close to *Parapandalus longicauda* (Rathbun), which has only been found in 88 fathoms in the upper Gulf of Mexico and off Porto Rico in 200 to 225 fathoms.

An additional specimen of *Pasiphaea merriami* described in last year's report and another large individual of the giant isopod, *Bathynomus giganteus*, a male approximately 13 inches in length, were secured this year.

The fair measure of success attending last year's attempts to record visually the life habits of some of the Tortugas reef dwellers encouraged a little more intensive work in this direction during the last days of the period I was enabled to spend in study at the laboratory. Results, so far as the development of the film has progressed, are much better than were those obtained the preceding season. Further studies were made of the burrowing jaw-fish, *Gnathypops*, constructing its home and showing resentment at the too near approach of other fish to the entrance of its retreat. In all, some 3200 feet of film were exposed.

*Effects of Radium Radiations on Regeneration in Euratella chamberlin,*  
by Raymond G. Stone

My studies on radiation and regeneration were continued from last summer. A more detailed investigation of the effects of combined beta and gamma radiations in comparison with those of the gamma rays alone

was undertaken. The sabellid, *Euratella chamberlin*,<sup>1</sup> used in these experiments has not previously been reported from this region although it is found in large numbers in the moat at Fort Jefferson.

Two groups of these worms were exposed simultaneously for varying periods in order to compare the differential effects of the rays. One group received the full output of beta and gamma rays from 123 mg. of radium. The other group was screened by a lead plate and received only gamma rays. The number and appearance of the new segments formed in posteriorly regenerating control-worms was the same as previously reported.<sup>2</sup> After removal of 4 to 6 anterior segments, normal worms regenerate only the head and collar segments at the cut surface. Histological examination of preserved material is necessary to discover whether the thoracic segments are replaced by transformation of abdominal segments as Berrill<sup>3</sup> reported in *Sabella pavonina*.

After 100 hours exposure to beta and gamma rays, the worms fail to replace anterior or posterior segments, though similar exposure to gamma rays alone has little effect upon regeneration. Apparently, therefore, the beta rays are chiefly responsible for the failure to replace lost segments. Sections of worms receiving the combined beta and gamma radiation show that wound healing is effected by rearrangement of adjacent old tissues without formation of new material. The new segments at the posterior ends of normal regenerating worms are mainly epithelial in origin. The epidermis and gut lining arise by proliferation of material from similar old tissues, while the nerve cord and mesodermal structures are formed from epidermal cells that push into the body cavity at the tip of the regenerating region. No undifferentiated reserve cells are found in *Euratella chamberlin*, although they are a source of new material during regeneration in other polychætes. The loss of regenerative powers after radiation in this worm is apparently due to direct effects of the rays within the epithelial cells.

#### *Study of the Reef Corals of the Tortugas, by John W. Wells*

The period of ten weeks, from June 1 to August 8, was spent at the Tortugas Laboratory. The study of the reef corals of the Tortugas was undertaken in connection with my work on fossil corals, a knowledge of the living corals and coral reefs being of great value in the interpretation of the more obscure fossil forms. The areal and bathymetric distribution of the different species, as well as the different growth-forms assumed under different conditions, was particularly emphasized. A total of 24 species (including two varieties or subspecies) of Madreporaria having a bathymetric range from low-water level to a depth of 25 feet was collected and examined. The distribution of the several types of associations of reef species was plotted on a chart of the Tortugas area.

During the dredging trips of the *Anton Dohrn*, specimens of eight species of "deep-sea corals" were taken in three hauls—at 39, 43 and 582 fathoms.

Experiments were conducted in an effort to determine the toleration of reef corals to increased salinity of sea-water. Specimens of the commoner reef species were placed in vessels containing sea-water evaporated to various concentrations, the salinity being roughly determined by titration.

<sup>1</sup> Identified by Dr. J. P. Moore, University of Pennsylvania.

<sup>2</sup> Carnegie Inst. Wash. Year Book No. 30, p. 395, 1930-31.

<sup>3</sup> Berrill, N. J., Jour. Exper. Zool., vol. 58, p. 495-523, 1931.

All of the specimens were placed in the water for 12-hour periods except in the case of salinity 50<sup>+</sup>, when the period was 6 hours. The results of these experiments are summarized in the following table:

Species	Salinity							
	40 <sup>+</sup>	43 <sup>+</sup>	46 <sup>+</sup>	48 <sup>±</sup>	50 <sup>-</sup>	50 <sup>+</sup>	55 <sup>-</sup>	70 <sup>-</sup>
<i>Eusmilia fastigiata</i> ...	Uninjured	.....	Uninjured	.....	Damaged	Recovered	Killed	.....
<i>Oculina diffusa</i> .....	.....	.....	.....	.....	.....	.....	Killed	.....
<i>Orbicella annularis</i> ....	Uninjured	Killed	Killed	Killed	Killed	Recovered	Killed	Killed
<i>Orbicella cavernosa</i> ....	.....	Uninjured	.....	.....	Do.	Do.	.....	.....
<i>Favia fragum</i> .....	Uninjured	Do.	Uninjured	.....	Uninjured	Uninjured	Injured	Killed
<i>Mæandra areolata</i> ....	Do.	Do.	Do.	Uninjured	Do.	Do.	Uninjured	Killed
<i>Mæandra strigosa</i> ....	Do.	Do.	.....	.....	Do.	Do.	Do.	Do.
<i>Mæandra clivosa</i> ....	Do.	Do.	Uninjured	Uninjured	Do.	Do.	Do.	Do.
<i>Agaricia agaricites crassa</i> .....	Do.	Damaged	Killed	.....	Killed	Recovered	Killed	.....
<i>Siderastrea radians</i> ...	Do.	Uninjured	Uninjured	Uninjured	Uninjured	Uninjured	Recovered	Killed
<i>Siderastrea siderea</i> ....	.....	Do.	.....	.....	Killed	Recovered	.....	.....
<i>Porites porites</i> .....	Uninjured	Do.	Killed	Killed	Killed	Killed	Killed	.....
<i>Porites furcata</i> .....	Do.	Do.	Do.	Do.	Do.	Do.	Do.	.....
<i>Porites astreoides</i> ....	Do.	Do.	Do.	Do.	Do.	Injured	.....	.....
<i>Acropora muricata</i> ....	Killed	.....	Killed	.....	.....	.....	.....	.....

These experiments, although of a preliminary nature, show that the hardier species of reef corals—*Favia fragum*, *Mæandra areolata*, *M. clivosa*, *M. strigosa* and *Siderastrea radians*—can endure a considerable increase in salinity at least for short periods of time, that most of the other species are killed by salinities in excess of 45, and that all are soon killed by a concentration greater than 55. It is probable, as Vaughan has inferred, that the reef corals of the Tortugas will not endure a concentration greater than the highest recorded for Tortugas water—36.29, for any considerable length of time.

#### *Studies on the Nematodes of Tortugas Fishes, by O. L. Williams*

More than 800 fishes representing about 175 species were examined for internal parasites during the summer of 1932. Although a careful study of the nematodes collected must be made before many conclusions can be drawn, a few preliminary observations may be recorded here.

A sufficient number of hosts has been examined to demonstrate rather clearly that the incidence of infestation with nematodes is somewhat lower in the fishes of the warm, shallow waters about the Tortugas than is the case in either the cooler, deeper waters of the same region or the cooler, shallow waters found farther north. Nematodes were collected from a

total of 80 species of fishes, or about 46 per cent of the different kinds of hosts examined. Inasmuch as the incidence of nematode infestation for a given species is usually low, further work will very materially increase the number of hosts known to bear nematodes occasionally.

Multiplication of species within a given host does not occur with the nematodes to the extent that it does with the trematodes. Not more than four kinds of nematodes were found in any one species of fish, and it is not expected that this number will be greatly increased. Furthermore, the number of nematodes parasitizing a single fish was found to be small in most cases. Extremely heavy infestations were found only in three groupers, *Epinephelus morio*, *Mycteroperca bonaci* and *Mycteroperca venenosa*. In these fishes, hundreds or even thousands of larval nematodes had become encysted throughout the viscera, being particularly abundant near the ends of the pyloric cæca.

Approximately two-thirds of the nematodes collected represent larval stages. Nearly all of these larvæ are sufficiently advanced, however, to make possible their identification. Although only a few of them have been determined as yet, it appears that many will prove to be the immature forms of species which normally mature in birds. With the completion of the study of the larval nematodes of fishes, a good starting point for life-history studies of the nematodes of marine birds may be found.



## ASTRONOMY

**Albrecht, Sebastian,** Dudley Observatory, Albany, New York. *Studies of radial velocities.*

Work has been continued on the problem of wave-lengths in the spectrum of a typical star of each spectral class. The determination of wave-lengths for the spectrum lines of the standard velocity star,  $\alpha$  Lyræ, class A0, and of  $\alpha$  Cygni, class A2, is well under way. The manuscript was completed for the class F5 star,  $\alpha$  Canis Minoris. Publication is being delayed until additional spectrograms to be secured on the new process emulsion can be studied.

At the Syracuse meeting of the American Association for the Advancement of Science, a paper was presented on "The Elimination of Coma Effect from Observed Stellar Wave-lengths." This paper discussed a method for accurately determining the effect on the observed stellar wave-lengths produced by a secondary coma of the camera lens of the spectrograph. The uncorrected coma produces a slight displacement of the strong reference lines away from the approximate center of the plate. For weak reference lines the coma wings are too faint to be photographically recorded. Although in radial velocity determinations the coma effect is automatically in part—for well-exposed plates almost entirely—eliminated, the total amount of the effect at any wave-length enters directly as a systematic error into the observed stellar wave-length. It must be eliminated in order that the stellar wave-lengths may be systematically homogeneous with laboratory wave-lengths. When many lines are measured, as is usually the case when stellar wave-lengths are to be determined, the exact nature of the coma effect can readily be determined for each plate. With the aid of the mean radial velocity, all displacements which are shared alike by all of the stellar lines are eliminated and the measures thus corrected are readily converted into observed wave-lengths. For the lines of known origin the differences "observed minus laboratory" wave-lengths are plotted with differences as ordinates and wave-lengths as abscissæ. The smoothed-out curve drawn through the plotted points represents the coma effect, and its amount at any wave-length is the ordinate of the curve at that wave-length. Application of corrections equal in amount to the ordinates but with signs changed will free the observed wave-lengths from the coma effect. The method was applied for  $\alpha$  Canis Minoris.

## BIOLOGY

Cannon, W. A., Stanford University, California. *Experimental studies on the relation of roots to oxygen, and on the aeration of plant tissues.*<sup>1</sup> (For previous reports see Year Books Nos. 2, 5, 8, 9, 11-25, 30.)

It has been shown in earlier reports that plants may have specific relations to oxygen, with especial reference to the roots, and that the oxygen requirement may be caused to vary directly with changes in temperature. It was also shown that the rate of consumption of oxygen by roots may be affected by the lighting conditions of the shoot or, in other words, by the rate of photosynthesis. Such relation, however, may be masked by temperature or by the evaporating power of the air, acting as limiting factors. However this may be, it appears possible that oxygen, which takes its origin in chlorophyll-bearing cells when provided with carbon dioxide and when properly illuminated, may be a feature of the aeration of plant tissues. The present report, therefore, has to do with the influence of humidity and the evaporation power of the air, and temperature, on the rate of oxygen absorption by roots. It deals also with the origin of "internal" oxygen,<sup>2</sup> and the possible ecological significance of the root-shoot relation as regards such oxygen.

### OXYGEN ABSORPTION BY THE ROOTS OF WILLOW (*Salix laevigata* BEBB)

Water cultures of willow were left for equal periods in darkness and in light. In sunlight they were exposed to the changes in temperature and evaporating conditions of the surrounding air although in certain experiments the rate of evaporation was increased by the use of a fan. And, in addition, a portion of the tests was run with the plants covered with a bell glass, but otherwise in full sunlight, over which water was run continuously. By this method, the temperature was fairly well controlled and at the same time the atmosphere of the bell glass was kept moist.

The leading results of the experiments, which refer to the relative rate of the oxygen absorption by roots when the shoot is in either sunlight or darkness, are as follows: When under a bell glass, in sunlight, the rate of oxygen absorption in 70 per cent of the experiments was less than for the same period in the dark. When exposed directly to sunlight, however, that is, without the bell glass, only 62 per cent of the tests showed a slower rate. All of these experiments were carried out in early spring; those of summer gave negative results only. It will appear, therefore, that in 30 to 38 per cent of the experiments the rate of oxygen consumption by roots was greater when the shoot was in sunlight than when it was in the dark. A study of the temperature of the solution and of the air about the shoot indicates that there may be an important temperature relation here. This is brought out in the following table which summarizes the temperature recorded for dark

<sup>1</sup> The research was carried out in part with the aid of a grant from the National Research Council.

<sup>2</sup> G. F. Beardsley and W. A. Cannon, *On the effects of a mud-flow at Mount Shasta on the vegetation*, Ecology, vol. 11, p. 326, 1930.

and light periods and in experiments with negative results (that is, an increase in the absorption rate), or positive results, during the periods of light.

Temperature of solution °C.				Temperature (C.°) of:			
Negative results		Positive results		Shoot Negative results		Root Positive results	
Darkness 21.7°	Light 22.4°	Darkness 22.1°	Light 22.2°	Darkness 22.0°	Light 25.0°	Darkness 22.0°	Light 24.0°

It will be seen from the table of averages that there is a correlation between the higher temperature of the light periods, both as to the solution (root) only and as to the shoot, and the more rapid rate of the absorption of oxygen by the roots (negative results). And, also, it will appear that where the temperature of the solution is alike for the two periods, positive results were obtained. That is, the rate of the consumption of oxygen decreased. This points to a possible supplemental supply of oxygen to the root at that time in addition to that derived by the roots from the solution in which they were placed. Only in event of relatively high temperatures, when the rate of respiration is correspondingly rapid, does it quite mask the effect in mind and accordingly act as a limiting factor.

#### EVAPORATION CONDITIONS OF THE AIR AND THE RATE OF CONSUMPTION OF OXYGEN BY ROOTS

It is known that the evaporation power of the air has a direct influence on the rate of photosynthesis, so that in extreme dryness, for example, it may go on at a very slow rate or cease entirely. In this event the evolution of oxygen ceases as well. Observations appear to indicate a close connection existing between such results and the oxygen relation of the root. Thus, it was observed that when the experiments were carried out without protecting the shoot from drying winds, the results were always negative. And experiments were set up in which the rate of evaporation was greatly increased by the use of a fan which played on the shoot. Quiet periods alternated with those with the fan, and in both instances the shoot was in direct sunlight. It was found, in brief, that the rate of oxygen absorption by roots during the period of active evaporation was from 50 to 200 per cent more rapid than during those in which the air was quiet. From the present view-point, therefore, it is concluded that under such rapid evaporation the rate of photosynthesis was less rapid than in the quiet periods, less oxygen was formed, and accordingly less was available to the tissues of the plant, including those of the root, and thus a relatively heavy drain was placed on the amount in the solution.

#### ORIGIN OF "INTERNAL" OXYGEN AND THE AERATION OF PLANT TISSUES<sup>1</sup>

In the course of the work, experiments were set up to learn whether oxygen might be evolved from the roots of sunflowers when in water cul-

<sup>1</sup> W. A. Cannon, *On the variation of the oxygen content of cultural solutions*, Science, vol. 75, p. 108, 1932.

tures. Both positive and negative results were obtained. But in several instances when the shoot was in sunlight, but protected by a bell glass, an increase in the amount of oxygen during the light period was demonstrated. This was 0.20 mg. per li., or less. Positive results depended on favorable temperature and high humidity, as was found in other experiments.

Additional experiments were carried out on cut leafy branches of apricot treated as in the case of the sunflower experiments referred to above. In several tests an increase in the oxygen concentration was seen to take place when the shoot was in sunlight, with humid atmosphere and with favorable temperature. Only negative results were obtained where the humidity was low.

Such preliminary experiments indicate, therefore, that the partial pressure of oxygen within the plant increases when the shoot is in sunlight, and further that such "internal" oxygen may play an important rôle in the aeration of plant tissues, including those of the root.

While it thus appears possible that "internal" oxygen may be present throughout the plant during photosynthesis, as indicated by some of the results given above, the partial pressure varies greatly. It is shown mostly by the decrease in the rate of the consumption of oxygen by roots while the shoot is in sunlight, but also, under certain conditions, it appears as an increase in the amount in solution in the medium in which the roots are located.

It is possible, therefore, that the oxygen of the aeration of plant tissues and organs may enter the plant directly from the atmospheric air, or it may enter the roots from the soil solution, or, finally, it may take its origin in photosynthesis. Whatever the relative importance of the three may be, all green plants may possibly use oxygen from all of these sources but not to the same extent, and not under all conditions. The ecological application of this conclusion, with especial reference to the light relation of species and therefore to the formation of "internal" oxygen, will be seen to be of much possible importance.

**Castle, W. E.,** Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-30.)

During the past year intensive study of heredity in rabbits and mice has been continued. The inheritance of body size, long one of our major problems, is receiving renewed attention. Having failed to detect evidence of the existence of genes controlling body size in four chromosome pairs, we are now adding two other chromosomes to the genetic complex which differentiates our large and small experimental races. If genes borne in chromosomes affect body size, evidence of such a relation should be demonstrable by linkage studies involving a sufficiently large number of the chromosomes. We have been unable as yet to detect such evidence in our own long-continued studies of the problem, and are skeptical of the evidence adduced by others from material less abundant and less well controlled than our own. We have found a positive correlation between developmental rate of the fertilized egg, birth-weight of the individual, and adult body size, as stated in previous reports. Whether this developmental



rate is affected by chromosomal genes or is due to plasmatic differences remains an open question on which we hope to obtain further information. Dr. P. W. Gregory, who cooperated in the embryological studies of size inheritance in the rabbit, is continuing the investigation at Davis, California, and reports finding in new-born young of large racial size a greater concentration of the sulphydrol compound glutathione than occurs in those of small racial size. Confirmation of this observation would establish a highly important relationship between body size and abundance of a particular sort of chemical compounds and might ultimately disclose whether the difference resides in nuclear or plasmatic constituents of the gametes.

A second line of investigation of the genetics of rabbits is concerned with mutations in hair length resulting in an abnormally short coat apparently devoid of guard hairs. We have now three such short-haired races, all similar in appearance but due to the action of different genes. Their genetic distinctness from one another is shown in that a cross between any two of them produces only young with hair of normal length. The mutations are thus shown to be distinct and complementary, although their somatic effects are indistinguishable. The earliest discovered and best known of these mutations is called *rex*. It originated in France some years ago. The second originated at Hamburg, Germany, and is there known as *Kurzhaar*. The third was discovered recently in northern France by Madame Du Barry, from whom I have been able to obtain a stock of animals for experimental study. They are known as *Norman rex*.

Linkage studies are in progress to ascertain whether these three genes lie in different chromosomes and whether any one of them is located in the same chromosome as any other known gene or genes. Other linkage studies in progress concern the genes for furless coat, yellow fat, and certain blood groups. Of the last named, two are known which are apparently due to allelomorphous genes. The presence in an individual of one or the other, or both or neither, of these genes is demonstrable by means of immune sera. Each gene determines the presence of a specific agglutinin in the red-blood cells. When blood containing either agglutinin is injected into the body of a rabbit which does *not* possess it, there is developed in its blood serum a specific antibody or *agglutinin*. Such serum will cause clumping of the red-blood cells of any rabbit which possesses the corresponding agglutinin, but will not clump blood cells of rabbits which lack it. The gene for either agglutinin is dominant over its absence in crosses. Both genes may be present in the same zygote and the blood of such individuals will naturally be clumped by either agglutinin. Thus neither agglutinin interferes with the action of the other. A serum containing both agglutinins may be produced by injecting blood of an animal containing both agglutinogens into an animal containing neither.

The agglutinogens are present in blood of new-born rabbits in as effective a form as in those which are full grown. This greatly facilitates study of linkage relations, as the mothers can be remated at once and large numbers of offspring obtained in a short time. Even in a prenatal stage, 14 days after mating of the mother, presence of agglutinogens can be demonstrated, so that in a litter expected to contain individuals of a blood group different from that of the mother, their actual occurrence can be shown. It thus

seems probable that the specific, blood-group agglutinogens are present in the red blood cells as soon as those cells are differentiated.

Individuals which lack both agglutinogens will have their blood clumped by *neither* agglutinin. But individuals which possess *both* agglutinogens transmit the respective genes *in separate gametes*, in which relation it will be found from a study of the pedigrees those genes had been inherited. In other words the genes for the two agglutinogens behave as allelomorphs and so can not enter into the same gamete, except by non-disjunction.

No linkage of a blood group gene with any other known gene has as yet been demonstrated but our canvass of the possibilities is yet incomplete.

One new linkage in the rabbit has been established by Dr. Sawin, between wide-banded agouti hairs and the gene for agouti. Dr. Sawin is also studying the variation in number of thoracic and lumbar vertebræ in the rabbit which appears to be considerable and to be subject to inheritance in a fairly simple way. These studies are being carried on chiefly at the Bussey Institution, although Dr. Sawin's academic connection is primarily with Brown University. Dr. C. E. Keeler also carries on his genetic investigations chiefly at the Bussey, although he has teaching and other responsibilities at the Harvard Medical School. He has made the blood group tests whose results have already been outlined, but in the making of the required sera, we have had the cooperation of Dr. L. H. Snyder, of Ohio State University but formerly associated with us at the Bussey. In the study of mouse genetics, Dr. Keeler has several new characters under observation, one of the most interesting of which is complete absence of the corpus callosum in the brain. This lack does not appear to interfere with the normal functioning of the nervous system. Its inheritance obviously depends on a single gene mutation.

**Dice, Lee R.**, University of Michigan, Ann Arbor, Michigan. *Ecological studies of Arizona mammals.*

A study of the ecological distribution of the mammals of the Santa Catalina Mountains was begun in early June 1932. This study, carried on in previous years by Philip Blossom, William P. Harris jr., and Lee R. Dice, is designed to extend to the summit of a mountain range, the survey of the mammals of the Tucson region.

Mount Lemmon, the highest peak of the Santa Catalina range, reaches an altitude of 9150 feet. The area in pine and in fir and spruce forest is relatively small. Nevertheless, in this montane region are found a tree squirrel, a chipmunk, a woodrat and a deer-mouse, none of which apparently occur on the surrounding desert areas. Relatives of these animals are known to occur on the upper parts of other desert mountain ranges. To explain this discontinuous distribution it seems necessary to postulate a somewhat more humid climatic period at some more or less remote time.

An ecological survey of the Chiricahua Mountains was begun by Victor Cahalane in late June 1932. It is planned to determine the mammal communities of the several life belts occurring on these mountains and in their vicinity.

A study of the relationship between the color of the smaller mammals and the colors of the soil and rock in the vicinity of Flagstaff was begun

in the middle of June 1932, by G. W. Bradt. Special attention will be given to several areas of black lava from which dark-colored races of mammals have previously been described.

**Longley, W. H.**, Goucher College, Baltimore, Maryland. *Preparation of a monograph on The Tortugas fishes.*

The organization of material gathered during many summers at Tortugas, and treating particularly of the habits of teleost fishes, has advanced materially since the Institution made it possible for me to devote my time chiefly to that end. By courtesy of the authorities in the several places, who have given me direct access to the rich collections in their charge in the Museum of Comparative Zoology of Harvard University, the U. S. National Museum in Washington, the American Museum of Natural History in New York and the Museum of the Academy of Natural Sciences in Philadelphia, I have been able to check material of my own collection against that which has passed through the hands of other students of West Indian fishes. Approximately half the work will be accomplished by the first of October.

Because of frequent and unforeseen difficulty in determining accurately what species actually compose the Tortugas fauna, progress has been much slower than was anticipated. With West Indian marine fishes whose identity it is wished to establish, it is at present not sufficient to check one's own against named specimens in museum collections, or even to check them against type specimens.

Taxonomists, working chiefly far from the point of origin of their material and having often relatively little for purposes of comparison—frequently, too, of necessity knowing little of its appearance in life and next to nothing of the place their species actually occupy in nature—have always found it difficult correctly to classify tropical marine fishes. After much reviewing, age, sexual dimorphism, instantaneous color-change and the accidents of imperfect preservation result still in single species masquerading as five, or rarely in as many as three, being regarded as one.

It is clear from the progress so far made that as high a proportion as one-fifth of listed species of marine teleosts of the West Indies are misconceived in their systematic relationships. The names in the register in that proportion are pure synonyms or more than a single species is included under them, as is suggested in the list appended.

It is to be hoped that its merit as a partial review of the West Indian marine fishes may sufficiently enhance the value of the finished work to justify the delay necessary in its completion.

NOTE—It is the writer's belief that the suggested changes in the rating of species mentioned below will be approved by students with access to adequate material. Some in the first group have already been in synonymy but reappear in Jordan, Evermann and Clark's *Check List of Fishes of North and Middle America*.

*Harengula sardina* Poey = *H. maculosa* Cuvier and Valenciennes = *H. clupeiola* Cuvier and Valenciennes = ? *H. macrophthalma* (Ranzani).

*Harengula pensacolæ* Goode and Bean = *H. humeralis* Cuvier and Valenciennes.

*Holocentrus puncticulatus* (Barbour) = *H. tortugæ* Jordan and Thompson = *H. coruscus* (Poey).

*Syngnathus robertsi* (Jordan and Rutter) = *S. elucens* (Poey).



- Hippichthys cayorum* (Evermann and Kendall) = *H. brachycephalus* (Poey).  
*Apogonichthys melampodus* Blosser = *A. stellatus* Cope = *A. puncticulatus* Poey.  
*Apogon sellicauda* Evermann and Marsh = *A. maculatus*. (Poey).  
*Epinephelus flavolimbatus* Poey = *E. niveatus* (Cuvier and Valenciennes).  
*Hæmulon mowbraji* Jordan and Evermann = *H. macrostomum* Gunther.  
*Anisotremus spleniatu*s (Poey) = *A. virginicus* juv. (Linnæus).  
*Pareques umbrosus* (Jordan and Eigenmann) = *Eques acuminatus* (Bloch and Schneider).  
*Centropyge lunata* (Blosser) = *Angelichthys isabelita* juv. Jordan and Rutter.  
*Chaetodon ateniatus* (Poey) = *Holacanthus tricolor* juv. (Bloch).  
*Acanthurus helioides* (Barbour) = *A. cæruleus* juv. Bloch and Schneider.  
*Scorpena atlantica* Nichols and Breder = *S. inermis* Cuvier and Valenciennes.  
*Peristedion gracile* juv. Goode and Bean = *P. imberbe* Poey.  
*Eupomacentrus chrysus* Bean = *Pomacentrus planifrons* juv. (Cuvier and Valenciennes).  
*Eupomacentrus nepenthe* Nichols = ♀ *Pomacentrus leucostictus* Müller and Troschel.  
*Pomacentrus analis* Poey = *P. atrocyaneus* Poey = *P. leucostictus* Müller and Troschel.  
*Pomacentrus caudalis* Poey = *P. flaviventer* Troschel = *P. xanthus* Poey.  
*Pomacentrus dorsopunicans* Poey = *P. adustus* Troschel = ? *P. fuscus* Cuvier and Valenciennes.  
*Pomacentrus freemani* Beebe and Tee-Van = *P. partitus* Poey.  
*Centrochromis rudis* (Poey) = *C. taurus* (Müller and Troschel).  
*Stegastes niveatus* (Poey) = *S. chrysurus* juv. (Cuvier and Valenciennes).  
*Iridio elegans* Bean = *Halichæres radiatus* juv. (Linnæus).  
*Iridio decoratus* Bean = *Halichæres garnoti* juv. (Cuvier and Valenciennes).  
*Iridio frenatus* Nichols = *I. similis* Nichols = *I. microstomum* Bean = *I. meyeri* Bean = *Halichæres maculipinna* (Müller and Troschel).  
*Bermudichthys subfurcatus* Nichols = *Thalassoma nitidum* (Günther) = *T. bifasciatum* (Bloch), female and young.  
*Doratonotus boekei* Metzelaar = *D. decoris* Evermann and Marsh = *D. megalepis* Günther.  
*Novaculichthys infirmus* (Bean) = ♀ *N. ventralis* (Bean).  
*Xyrida jessæ* (Jordan) = *Xyrichthys psittacus* (Linnæus).  
*Xyrichthys binghami* Mowbray = ♂ *Xyrichthys psittacus* (Linnæus).  
*Cryptotomus crassiceps* Bean = ♀ *C. roseus* Cope.  
*Cryptotomus retractus* (Poey) = *C. dentiens* (Poey).  
*Sparisoma niphobles* Jordan and Bollman = *S. xystrodon* Jordan and Swain = *S. hoplomystax* (Cope) = *S. humeralis* (Poey) = *S. atomarium* (Poey) = *S. radians* (Cuvier and Valenciennes), sexes and color phases.  
*Sparisoma lorito* Jordan and Swain = *S. brachiale* (Poey) = *S. chrysopterum* (Bloch and Schneider).  
*Scarus gnathodus* (Poey) = *S. acutus* Poey.  
*Pseudoscarus plumbeus* Bean = *P. simplex* Poey = *P. cælestinus* (Cuvier and Valenciennes).  
*Gobius translucens* Nichols = *Rhinogobius glaucoprænum* (Gill).  
*Xenogobius weberi* Metzelaar = *Microgobius signatus* Poey.  
*Callionymus sancti-eustatii* Metzelaar = ♀ *C. boekei* Metzelaar.  
*Gnathypops mystacina* Jordan = *Opisthognathus lonchurum* Jordan and Gilbert.  
*Auchenopterus rubescens* Evermann and Marsh = *A. albicaudus* Evermann and Marsh = *A. affinis* (Steindachner).  
*Auchenopterus nox* (Jordan and Gilbert) = *A. fasciatus* (Steindachner).  
*Auchenopterus fajardo* Evermann and Marsh = *A. nigripinnis* (Steindachner).  
*Labrisomus lentiginosus* Bean = *L. microlepidotus* Poey = *L. herminier* (LeSueur) = *L. nuchipinnis* (Quoy and Gaimard).  
*Erieteis kalisheræ* Jordan = *Labrisomus bucciferus* Poey.  
*Malacotenus puertoricensis* Evermann and Marsh = *M. bimaculatus* (Steindachner) = *M. varius* (Poey) = *M. biguttatus* (Cope).  
*Malacotenus moorei* Evermann and Marsh = *M. macropus* (Poey).  
*Brannerella culebræ* (Evermann and Marsh) = *B. brasiliensis* Gilbert = *B. ocellatus* (Steindachner).  
*Blennius stearnsi* Jordan and Gilbert = *Blennius favosus* Goode and Bean = *Blennius marmoreus* Poey.  
*Blennius truncatus* Poey = *Rupiscartes atlanticus* (Cuvier and Valenciennes).  
*Scartella microstoma* (Poey) = *Blennius cristatus* Linnæus.  
*Entomacrodus margaritaceus* Poey = *Salarichthys textilis* (Quoy and Gaimard).  
*Stathmonotus tekla* Nichols = *Auchenistius stahli* Evermann and Marsh.  
*Balistes moribundus* Cope = *B. capriscus* juv. Gmelin.  
*Antennarius tenebrosus* (Poey) = *A. tigris* (Poey) = *A. scaber* juv. (Cuvier).  
*Antennarius astroscopus* Nichols = *A. verrucosus* Bean = *A. corallinus* Poey = ? *A. multiocellatus* (Cuvier and Valenciennes).



*Diplectrum bivittatum* (Cuvier and Valenciennes), *Hypoplectrus indigo* (Poey), *Hypoplectrus gemma* Goode and Bean and *Xyrichthys lineata* (Gmelin) are perfectly distinct from the species with which they are currently united. Under the name of *Apogon maculatus* (Poey) authors include, in addition to the proper species, a very distinct one common in museum collections. It is the black-finned type referred to in their description of *Apogon sellicauda* by Evermann and Marsh. It has fewer and more regularly arranged scales than the true *maculatus*, and may be called *Apogon pseudomaculatus*.

The viviparous genus *Ogilbia*, if distinct from *Dinematichthys*, is to be distinguished not by absence of clasping or intromittent organs, but by the details of their structure.

**Mann, Albert**, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of studies on Diatomaceæ*. (For previous reports see Year Books, Nos. 18-30.)

A much needed improvement has been made this year in the usefulness of the large diatom collection of our laboratory at the United States National Museum. Since the beginning of diatom research under the grant of the Carnegie Institution, the yearly increase in this collection has outstripped our power to card-catalog and arrange on a scientific plan the thousands of specimens added by our own work and by outside contributions. Much delay and confusion in finding species known to be in the collection has resulted from this and has hampered our own studies and made this extensive collection of type forms less serviceable to visiting scientists. We, therefore, employed for two months Miss Estella Humphrey, a graduate of Wellesley College, to thoroughly rearrange and card-catalog the 8000 or more named specimens in the laboratory.

Miss Easter Cupp, assistant to Professor W. E. Allen of the Scripps Institute of Oceanography at La Jolla, California, spent October and November 1931 in the laboratory, studying methods of diatom investigation and becoming familiar with the genera and species represented in the laboratory collection.

Mr. Ralph Shropshire, of the Buffalo Museum of Science and a member of the Byrd Antarctic Expedition, spent a week at the laboratory in consultation as to the validity of diatom species in material collected by him in the Antarctic. Among these were 16 species, for which original descriptions were furnished for incorporation in his report.

Mr. Robert Hagelstein of Mineola, Long Island, spent four days at the laboratory in consultation regarding the identification of diatoms in material collected by him in Porto Rico and the Virgin Islands. The marine material was secured during the expedition of the New York Botanical Garden to the West Indies. The results of Mr. Hagelstein's studies will be published in an illustrated report on *Diatoms of Porto Rico and the Virgin Islands*. Mr. Hagelstein presented to the laboratory a recently issued work, Barston, *See Diatomeen*; also 75 mounted specimens from Porto Rico and a large number of photographs of diatoms.

Twenty unusual diatoms from Mexico were identified for Mr. Frederick Adams, Bournemouth, England.

Some diatoms with unusually large pores were supplied to Professor T. E. Phipps, of the University of Illinois, for use in studies of the hydrogen atom. Each diatom was to be cemented over the central aperture of an extremely fine thermometer tube, a delicate metal film spread over the diatom and the hydrogen atoms shot through the metal film and the underlying diatom pores into the tube.

Mr. Philip O. Graville, of South Orange, New Jersey, a professional photomicrographer, was supplied with four mounts of the largest known diatom, *Coscinodiscus rex* Wall. Copies of the photograph of this relatively huge but very delicate diatom and 10 finely mounted photographs of diatom groups were sent to the laboratory.

The diatom exhibit at the annual meeting of the Institution last December consisted of 10 large transparency photographs of 10 species, each shown in pairs, one specimen of each pair being a fossil diatom from the lower Miocene and its companion specimen a recent diatom from the waters of Chesapeake Bay. Although the fossil member of each pair was fully twenty-million years old, there was shown to be a practically identical duplication in the 1931 representative of each species. In addition to the transparencies, similar paired diatoms were exhibited under microscopes. The purpose of exhibit was to demonstrate that while diatoms as a group have changed enormously since their first appearance on earth, certain species have maintained with rigid exactness all their ancestral characteristics, through millions of years, despite the many great changes in environment that have wrought such extensive modifications in the structure of other living things around them. There is at present no known explanation of these striking examples of suspended evolution.

Mr. Wm. A. Robinson, who completed a world voyage of over three years in a 32-foot sailing boat, made occasional diatom gatherings for the laboratory at the suggestion of Captain Ault of the *Carnegie*. The investigation of these samples, obtained in some of the most unfrequented islands, have yielded a large number of rare and hitherto unknown species and genera. All the material has now been studied and Mr. Robinson has been asked to continue these collections during a similar voyage which will start during the Autumn of 1932.

Studies have been made of some rich diatom material sent in from the Gulf of Siam by Dr. Hugh M. Smith, engaged in establishing a Siamese Fish Commission at Bangkok. Material from this tropical part of the world has been only slightly investigated and further knowledge of the distribution of species there is much to be desired, especially in its bearing on problems of transportation of marine life by ocean currents.

During the recent excavations on the site of the old market in Washington a fresh-water sub-fossil swamp area was uncovered. Samples of the dark gray muck were taken and were found to be rich in diatoms. Investigation of this material is not complete, but the species already identified show a close similarity to the diatom flora of the cypress bog uncovered on the site of the Mayflower Hotel on Connecticut Avenue and to the fossil diatom beds at Montgomery, Alabama, a report of which was published by the Washington Academy of Sciences.

Fifty-four species of marine diatoms were found on a frond of alga from the west coast of Costa Rica, a report of which was sent to the collector, Sr. Manuel Valerio of the Lyceum of Costa Rica at San José.

Investigations were completed of the extensive collections from the lakes of British Columbia made by Professor Wm. R. Taylor of the University of Michigan and 160 species were listed in the report to be included in Dr. Taylor's publication. The species were distinctly alpine and sub-alpine as to locality, but far less contrast between the two was shown by the diatoms than by the other groups of plants and animals from the same localities. This agrees with the findings of Frege in Greenland by his study of gatherings made from sea-level to an altitude of 2200 feet.

All the dredgings secured by the *Carnegie* on its last voyage were cleaned and their diatoms partly identified last year. This work has now been completed and many rare species, as well as some new ones have been secured. Photographs of the latter will shortly be made and a full report prepared. The great number of plankton samples obtained is also being examined. In the opinion of the writer, these are of far less significance than the bottom diatoms, both as to geographical distribution and their interrelation with marine animal life, therefore, a less exhaustive method of study is being adopted than that used in the case of the dredgings. It will, however, amply record the characteristic plankton diatom flora at the time and in the localities where the collections were made.

A report was made to Miss McCoy of the Department of Agricultural Bacteriology, University of Wisconsin, on the comparative aspects of two samples from the bottom of Lake Mendota at Madison, both in 65 feet of water. One was from the surface of the bottom, the other from 4 feet below the surface.

Ten abstracts of recent diatom literature were prepared during the year for publication in "Biological Abstracts."

Fewer requests for information as to the quality of samples of fossil diatom material were made this year than in former years. This probably was due to a natural decrease in the number of new fossil deposits discovered and also to a falling off in demands for diatomite because of decreased activity in manufacture.

**Morgan, T. H., C. B. Bridges and Jack Schultz**, California Institute of Technology, Pasadena, California. *The constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15-30.)

The work of building up the chromosome maps of *Drosophila*, that has been going on for twenty years, mainly with the support of grants from the Carnegie Institution of Washington, continues. A great part of the detailed experimental work with the *Drosophila* material that is being carried out in almost every country of the world depends on the accurate location of the genes. This is especially true in connection with the study of environmental effects on crossing over, and with the translocation of a part of one chromosome on to another one, producing thereby a new linkage group. As new mutants appear from time to time, it is possible not only to fill empty regions of the chromosomes, but in some cases—



when the new mutant is a more workable type—to obtain more accurate data for regions of the map where many genes have already been placed. The present report includes an account of some new mutant genes and their locations, the effects on crossing over resulting from the attachment of a piece of one chromosome on to another, and work on a new kind of problem in connection with the interrelations of different chromosomes during crossing over. The presence of translocated pieces introduces new genetic problems; the loss of a section of a chromosome—a so-called deficiency—introduces a different set of problems. Sometimes translocations and deficiencies occur under “natural” conditions, *i.e.* where a special environmental effect is not known to have brought about the change, but the same effects are now being produced on a larger scale by treating the flies with X-rays. The principles involved and the method of identification of the effects had been worked out several years before the X-ray treatment furnished more abundant material for work of this kind. The success of such work depends to a great extent on the accuracy with which genes have been located. For this reason, as well as others, it is important to continue to carry out rather extensive work on localization of the genes of *Drosophila*.

Considerable work on the spacing and order of the many genes clustered at the extreme right end of the second chromosome has been done. For example, a purploid-lanceolate<sup>2</sup>-speck stock was secured and back-crosses run. The purploid-lanceolate<sup>2</sup> recombination percentage was roughly 0.4, and the lanceolate<sup>2</sup>-speck roughly 0.2 unit. The locus of abbreviated has been found to be about midway between those of brown and speck, derived after a brown-abbreviated-speck stock had been obtained by continued testing. A recessive intensifier of abbreviated has been found, with which the separations of abbreviated *versus* nonabbreviated are easy and reliable.

The allelomorph brown<sup>2</sup>, which was at one time thought to be more useful than the original brown, has been found to possess a slight crossing over reducer, which when present persistently gives about 1.4 instead of the standard 2.5 for bw-sp. The locus of the reducer is at the left of that of bw<sup>2</sup>. It can be removed by crossing over.

Three excellent new mutations have been found which have their loci in the vacant space between curved and plexus at the right end of chromosome II. These three loci improve the map very much, connecting the terminal group about plexus brown and speck with the group about Lobe and curved. The new characters are far more useful than fringed, narrow and humpy, which were hitherto the best available in this long gap.

Besides the mutant loci mentioned above, about twenty other mutations in chromosome II have been localized. Some have been incorporated into multiple stocks for improving the experimental control of crossing over in special sections.

Twenty-six special multiple stocks have been synthesized and much of the counting done for three sets of alternated experiments on crossing over in the X-chromosome from scute to bobbed. This work extends the previous work with X-ple and alternated X-ple, which covered the distance from scute to forked. Complete correction curves for the X-chromosome can now be prepared. Similar work, both for the entire length of chromosome II and for an intensive study of the left limb is now about half completed.



The original Pale-translocation (1917, 1923) involved a break of chromosome II at about the locus of plexus, and the lateral attachment of this terminal fragment to the third chromosome at about the locus of Hairless. It was interesting to examine the effects on crossing over, both between chromosome II, lacking the translocated piece, and its normal mate; and between the piece, now attached to chromosome III, and its homologous portion in the normal second chromosome.

The effect of Pale-translocation on crossing over in chromosome II, was known from an experiment carried out in 1920 to be a reduction to about half the normal amount in the Lobe-humpy section just to the left of the point of break. No crossovers to the right of the point of break had been detected. In a ten-day transfer experiment, producing 4000 flies, the following recombination percentages were found: al-dp. 11.8, dp-b 23.9, b-B1 5.7, B1-L<sup>c</sup> 12.6, L<sup>c</sup>-P 10.7, P-sp 0.1. For the control experiment in which no Pale-translocation was present, the values were: al-dp 12.0, dp-b 24.7, b-B1 3.8, B1-L<sup>c</sup> 12.3, L<sup>c</sup>-px 23.2, px-sp 6.0. From the comparison of these figures it is clear that the effect of the translocation is negligible, except in the interval from Lobe to the break, where it is 10.7 instead of the control 23.2, and in the region to the right of the break where a total of 6 flies was apparently due to crossing over involving the normal second chromosome and the translocated end fragment attached to chromosome III.

The preceding data show crossing over between the translocated portion and the normal chromosome II. This is also apparent from another experiment in which five such crossovers were noted. In this experiment it was sought to increase the frequency of synapsis between P-III and the normal II by weakening both rival attractions. This was done by an inversion (Sb C'') in the non-P-III third chromosome and by Nova Scotia C-IIR in the non-P-II second chromosome.

A closer analysis of this effect of Pale-translocation upon crossing over in the region just to the left of the break has been carried out by the ten-day transfer method on a very large scale. The data yielded a total of 3145 flies on which the most reliable calculations can be made (7/8 of all zygotes were discarded). Of these 418, or 13.3 per cent, came from crossing over between L<sup>c</sup> and humpy; 58, or 1.8 per cent between humpy and arc; and 12, or 0.4 per cent between arc and the break. The strictly parallel control experiment is not yet completed, so one can only conclude from general linkage data that the strongest proportional reduction has been in the region to the right of humpy—that is, nearest the break.

In another experiment both of the second chromosomes were normal, but one member of the third chromosome-pair carried the translocated portion (P-III). The problem involved here concerns the influence of this duplication fragment on crossing over between the normal second chromosomes. This was tested in a ten-day transfer experiment in parallel to the other test, but on a smaller scale, since only 1500 flies were secured. The recombination percentages were: al-dp 10.9, dp-b 27.1, b-B 5.4, B-L<sup>2</sup> 14.2, L<sup>2</sup>-px 25.1, px-sp 7.3. There is no evidence here of an interference by the duplication on the crossing over, doubtless because the piece involved is so short in relation to the length of the two normal chromosomes.

The effect on crossing over due to a terminal deficiency Plexate has been tested. Plexate, as previously reported, is a deficiency for speck, blistered, balloon and a lethal, all of which constitute the extreme right-end region of the map of chromosome II. In a very carefully executed experiment, involving 4000 flies from mothers transferred daily through half-pint bottles for the first ten days of their life, the following recombination percentages were obtained: aristaless-dumpy 11.8, dumpy-black 22.0, black-Bristle, 4.7, Bristle-Lobe<sup>e</sup> 14.1, Lobe<sup>e</sup>-brown 28.6, brown-Plexate 1.7; total 82.9. From an equal volume of similarly obtained control data, in which Plexate was replaced by speck, the following recombination percentages were obtained: al-dp 12.3, dp-b 23.1, b-B1 2.8, B1-L<sup>e</sup> 13.5, L<sup>e</sup>-bw 27.6, bw-sp 2.9; total 81.2. From a comparison of these values it is evident that if there is any effect it is a decrease in the region of the deficiency.

As a further step in the analysis of interchromosomal effects in crossing over, experiments have been carried out, in collaboration with Dr. Helen Redfield, to test the effect of inverted sections in one chromosome on crossing over in another non-homologous chromosome. Crossing over in chromosome III (marked by the genes  $\frac{ru \quad st \quad ca}{h \quad H}$ ) was studied (1) when chromosome X and II were normal; (2) when X contained the inversion ClB and chromosome II was normal; (3) when X was normal and chromosome II contained the inversions associated with Curly; and (4) when both the X and II contained these inverted chromosome sections. In the presence of inversions in the other chromosomes, crossing over in chromosome II is increased, the increase being greatest in the regions h-st, st-H. For example, the ratios to the normal values, of those obtained in the experiment with ClB Curly are as follows: ru-h:  $1.22 \pm 0.04$ ; h-st:  $1.73 \pm 0.07$ ; st-H:  $1.88 \pm 0.07$ ; H-ca:  $1.16 \pm 0.03$ . The total map length in this experiment shows an increase of 42.0 units over the normal. When both inversions are present simultaneously, the crossing over is highest, the effects of the individual inversions being apparently cumulative. The increase is due largely to an increase in the number of multiple crossovers, whose proportion is highest in the C B Curly experiments, lowest in that involving the normal X and II. These experiments, which suggest a variety of others designed to distinguish between various theoretical possibilities, show interchromosomal effects on a larger scale than any hitherto performed.

The mosaic eye-color Plum, described by Muller (1930) and by Glass (1932), is a dominant allelomorph of the recessive eye-color brown, lying at the right end of chromosome II. Glass describes Plum as associated with a complex inversion in this chromosome. It now appears that Plum also behaves as an allelomorph of the eye-color light, located in the same chromosome at 55.0. The Plum/light compounds are like light, but show characteristic dilute patches in the eye. Since Plum/brown does not show such patches, this may indicate that the brown locus is the one concerned with the mosaic character. The relation of these allelomorphic effects to the ends of the inversions in this chromosome, as well as to the dominance of Plum, should throw some light on these cases of "eversporting" chromosome rearrangements.

With the excellent *Drosophila* material on hand, it has also been possible to study the effects of the genes in the development of the individual from a physiological point of view. For example, the work with the eye-colors of *Drosophila* shows that the various types apparently fall into three groups. Histological studies of some twenty races, both single mutant types and their combinations, show that in the "vermilion" group orange-red granules are chiefly present. In the "garnet" group orange-red granules are predominant in the secondary pigment cells, and yellow granules in the primary cells. Finally, in the "prune" group, wine-red granules predominate in the secondary cells, yellow in the primary cells. In the wild-type, both the red and yellow granules are present in both types of cells, with the red preponderating. Previous studies have shown that from all these types the same red and yellow pigments may be extracted, and that these may be converted into a third (brown) pigment, which is present in the body of the flies. New data indicate that the brown pigment does not, as was formerly believed probable, occur in the eyes themselves in any of the types studied. In smears of the eyes of the "prune," and to a lesser degree of the "garnet" groups, it is found that the red and yellow pigments form a reversible oxidation reduction system with each other, although in solution both are oxidized to a colorless substance by hydrogen peroxide. The reversible change of yellow to red may be effected in the intact fly by the use of  $H_2S$  or other gaseous reagents of the proper reduction potential. Anaerobiosis is ineffective in producing the change, as also are various enzyme poisons.

In the normal development of the eye, the first color to appear in the pupa is a light tan. This also changes to red on treatment with reducing agents. If a sub-lethal treatment is given, the change is reversed when development proceeds. Later, in the wild-type, when about 75 to 80 per cent of pupal development is completed, the eye-color changes naturally from tan to red. The color changes in pupal development have been timed in 23 different eye-color types, and it seems that here the grouping inferred from the histological evidence is also apparent. The first appearance of color occurs in the "prune" group when about 50 to 55 per cent of pupal development is completed; in the "garnet" group slightly later, and with an apparently slower rate of increase, as judged by simple observation; and in the "vermilion" group when as much as 65 to 70 per cent of pupal development is completed. The first color to appear in all cases is the tan, or yellow, which may be changed to red by treatment with  $H_2S$ . The possibility of such a grouping makes a study of the interaction effects in the eye-color series of considerable interest. Over a hundred different genetic combinations have been observed, and it appears that qualitatively the rule holds that combinations between the various groups show marked dilution effects, whereas combinations within a group have generally the appearance of the more dilute component. The data lend themselves to an elaboration of this rule, in terms of the times at which the differential developmental reactions occur. According to this, the grouping of the eye-colors is determined by several relatively independent reactions occurring at different times in development.



## GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Investigations in the genus Crepis*. (For previous reports see Year Books 25-30.)

Progress in the *Crepis* investigations during the past year may be summarized under three heads: taxonomic research; cytogenetic research; miscellaneous studies.

### TAXONOMIC RESEARCH

Primarily these studies aim to arrive at conclusions pertaining to classification, phylogeny and evolution by combining evidence derived from taxonomic research with the evidence from cytogenetics and other studies. This method of attack calls for an attitude of suspended judgment on many questions and makes the preparation of a taxonomic monograph a more complicated and slower undertaking than one in which classification is based merely on comparative gross morphology. The end result, however, should justify the longer time and greater expense involved, not only because the classification of *Crepis* is in itself a difficult undertaking, but also because application of the synthetic method leads to discovery of new facts and principles of wider biological significance. The general problems of classification involved are, first, determination of the natural limits of the genus; second, classification of the 200 or more known species of *Crepis* according to their natural relationships.

*Generic limits*—This difficult problem involves the relationships of some 35 species, many of which are rare and little known. Of these, about 25 which were previously classified under *Crepis* are to be transferred to various other genera, and about 10 which have been classified under two other genera are to be merged in *Crepis*. These conclusions were reached through critical study of external morphology and the chromosomes.

*Classification of Crepis*—Critical study of herbarium material has been continued. Many new specimens have been received from foreign collectors. Sixty species have been grown; during the past year 27 of these were grown for the first time. From these cultures, herbarium specimens have been prepared for future reference. Growing of cultures and preparation of herbarium material has been done by C. W. Haney.

*Progress on monograph*—As a result of the foregoing studies, plans for a monograph are taking more definite form. Recent additions to our collection of living species make possible some improvements in earlier treatments of the phylogenetic relations within the genus. Subgenera and sections are becoming more definitely recognized. It is proposed to illustrate practically all of the 200+ species. About 150 plates have been completed. The writing of descriptions has proceeded more slowly, but some progress has been made during the past year.

### CYTOGENETIC RESEARCH

*Chromosomes of species*—Study of the chromosomes of 21 species not previously investigated cytologically is completed. Typical figures for



each species are drawn and filed for comparison in working out phylogenetic relations and finished drawings are made for publication.

*Interspecific hybrids*—This work has two phases. (a) Obtaining evidence on degree of relationship between species by experiments on crossability, viability and fertility of hybrids. During the past year, 19 new interspecific hybrids have been produced; and some of the more fertile earlier hybrids have been repeated and backcrossed on the parents. This routine hybridization work has been carried on by Mr. Haney who reports the total number of good hybrid seed produced as 1600 and total backcrossed seed as 864. (b) Intensive studies of the cytogenetics of species hybrids, their parents and derivatives for the purpose of adding to our knowledge of chromosome behavior in relation to phylogeny and evolution. Six such intensive studies are under way as follows: derivatives of the *Crepis rubra* x *fætida* amphidiploid by C. F. Poole; derivatives of *C. nicæënsis* x *setosa* by S. L. Emsweller; hybrids of *C. dioscoridis* x *argolica* and *dioscoridis* x *tubæformis* by F. L. Smith; derivatives of *C. aspera* x *aculeata* by E. C. Lagomarsino; hybrids of *C. fætida* x *commutata* and *fætida* x *eritreënsis* by Mrs. M. S. Cave; hybrids involving *C. canariensis*, *divaricata*, *hieracioides* and *laciniata* by J. A. Jenkins.

#### MISCELLANEOUS STUDIES

(1) The problem of how *Crepis tenuifolia* maintains 15 chromosomes in its somatic cells under reproduction from seed is being investigated by Dr. Poole, who is making cytological studies of the living plants. (2) The degree of variability in pollen morphology in *Crepis* species and its relation to taxonomy is being studied by Babcock and Poole. The pollen of 50 species has been examined, thus producing some evidence of value in connection with generic limits. (3) Artificial germination of *Crepis* pollen is being investigated by Mr. Milo N. Wood of the U. S. Department of Agriculture in connection with his work on pollen germination in fruits. The composites are notoriously difficult in regard to artificial pollen germination and thus far Mr. Wood has failed to discover a satisfactory medium for *Crepis*. (4) Interspecific relationships among three small groups of *Crepis* species are being studied through work on the living plants by Miss M. M. Richardson, Commonwealth Fund Fellow.

**Banta, A. M.**, Brown University, Providence, Rhode Island. *Completion and preparation for publication of studies with Cladocera.* (For previous report see Year Book No. 30.)

The available time during the past year has been employed in writing up the accumulated material on the genetics of Cladocera. Unexpected occurrences have limited the amount of time available for this major undertaking. Nevertheless real progress has been made.

The long-time program of the study of the accumulation of recessive mutations during continued parthenogenesis in *Daphnia longispina* has been followed.

A preliminary study by Thelma R. Wood and George A. Smith of the variability of the young hatched from sexual eggs of *Moina macrocopa* shows that with this species (as with *Daphnia longispina*) recessive muta-

tions occur and accumulate during successive parthenogenetic generations and reveal their effect only with the segregation and recombination accompanying sexual reproduction.

The inheritance of dwarfness in *D. longispina* has been fairly satisfactorily determined. Dwarfness is dependent upon a simple recessive Mendelian factor. The relationship between dwarfness and slow rate of development *per se* is not yet clear. Slow rate of development and growth is a factor in dwarfness. Not all "slow developers" become dwarfs, however; those slow developers which continue growth, past the time when increase in size normally becomes relatively slight, attain approximately normal size. Obviously there is a factor (or factors) determining the slowing down of growth at sexual maturity.

With Dr. L. A. Brown's cooperation, further analysis has been made of the relationship between the quantity of food and crowding in control of sex in *Moina macrocopa*. In crowding experiments quantity of food appears to be a very minor factor.

With Dr. C. A. Stuart's cooperation, we have made a fuller analysis of the critical period for sex control in *M. macrocopa*.

Thelma R. Wood's experiments on methods of securing and hatching sexual eggs of Cladocera have produced a very successful and useful technique. Some of Miss Wood's incidental observations on Cladocera are not only new but are of general biological and evolutionary interest.

Students at Brown University working with Cladocera material have advanced information on two problems of general biological interest, though not related to genetics. C. D. Williams demonstrated that (for the organs studied) capacity for regeneration is not coordinated with the functional value of the organ excised. In his case the useless or nearly useless organ was completely restored; the highly functional organ quite imperfectly regenerated. R. P. Ash procured some fairly good evidence, confirming certain of our previous observations, that under optimum conditions *Moina macrocopa* will have a shorter life than under conditions of moderately severe stress.

## MATHEMATICS

**Morley, Frank**, Johns Hopkins University, Baltimore, Maryland. *Construction and application of models based upon results of studies in inversive geometry.*

Through support of funds made available for this purpose, three mechanisms have been constructed by the London Instrument Company. Dr. Morley has also arranged for preparation of a fourth mechanism, designed to draw the important logarithmic spiral.

During the past year Dr. Morley has published four notes on the inversive geometry in the American Journal of Science.

## METEOROLOGY

**Bjerknes, V.,** Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-30.)

The work of the current year has been devoted entirely to completion and publication of the book *Physical Hydrodynamics with Applications to Meteorology* by V. Bjerknes, J. Bjerknes, H. Solberg and T. Bergeron. The book is appearing simultaneously in French in Paris and in German in Berlin. It will be of about 800 octavo pages, of which two-thirds are now printed. A general summary of the content was given in the last annual report, but supplementary results and general views of great importance should be mentioned here.

### FLIGHT OF BIRDS AND INSECTS

Modern aerodynamics have taught us to calculate the force which lifts airplanes and explain the sailing flight of birds. But no method has heretofore been given for calculating, upon dynamical principles, the effect of the pull of an oar or of the blow of the wing of a bird or an insect. By use of the formulæ belonging simultaneously to hydrodynamics and to electromagnetism, which are subjects of careful development in the book, it proves possible to arrive at good, first approximations of these forces. Thus it is known that birds under normal flight lift only a part of their weight by the blow of the wings, the rest being lifted by the sailing effect in the intervals between the successive blows of the wings. For insects, who can stand still in the air, it is found that the blows downward lift more than their weight, the excess compensating for the depressing effect of the blows upward.

### INSUFFICIENCY OF THE LAPLACEAN THEORY OF THE TIDES

Newton's "equilibrium theory" of the tides gives the principle for the explication of the tidal phenomena, but it is incomplete as it neglects the "free" oscillations of the seas. The aim of Laplace's "dynamical" theory of the tides was to take fully into account all these free oscillations. He succeeded in giving a satisfactory theory in regard to the semidiurnal tides, but failed entirely to explain the diurnal tides, for which his main conclusion was: "La marée diurne est nulle si la profondeur de la mer est constante." Of this statement, one of the greatest authorities on the theory of the tides, G. H. Darwin, says: "In fact the evanescence of the diurnal inequality is not much closer to truth than the large inequality predicted by the equilibrium theory; and both theories must be abandoned as satisfactory explanation of the true condition of affairs." But no one has succeeded in pointing out the reason for the failure. All authors, including Kelvin and Poincaré, have retained the fundamental equations laid down by Laplace and have tried to improve the theory by finding sufficiently general integrals of them. No one has thought of seeking the error in *the fundamental equations themselves.*



Professor Solberg's discovery of "cellular inertia oscillations" and "cellular inertia waves" in rotating fluid masses, such as the sea (see Year Book No. 28) has cleared up the question. This type of oscillations or waves does not appear in the solutions of the Laplacean equations, and can not appear in these solutions on account of an inadmissible approximation. In order to simplify the problem, Laplace, as well as all his successors, have replaced the equation of motion along the vertical coordinate by the *equilibrium equation*. In other words, Laplace has not made the full step from the Newtonian equilibrium theory to an exact dynamical theory, but only the half step to a *half-dynamical* theory. For this reason the inertia waves, with or without free surface, have dropped out of his theory and, thereby, every diurnal tide of any importance. The following example may be instructive. Suppose the sea to form a canal 2000 meters deep and limited by vertical walls at the tropics of the Cancer and of the Capricorn. In this canal, inertia waves with free surface would propagate around the earth in 24 hours; and as there would then be *resonance* between the free waves and the diurnal tide-generating force, devastating tides would be produced.

The entire theory of the tides must therefore be recast. The general character of the exact theory may be foreseen: the old Laplacean theory will remain a good, first approximation for the semidiurnal tides, while a new theory will be found for the diurnal tides. It has not been possible to take up the new theory of the tides in this book, but the subject will be considered later.

#### WAVE THEORY OF CYCLONES

Doing away with old errors is often a necessary condition for progress. Thus, it would not have been possible to work out the wave theory of cyclones upon a reliable basis, without first clearing up the insufficiency of the Laplacean theory of the tides. As a matter of fact, from the beginning we followed Laplace's example on account of its apparent mathematical simplicity, until this only half-dynamical method proved at fault. Using the exact theory, about two years ago, Professor Solberg succeeded in finding a type of wave, propagating along the boundary surface between two isothermal layers of air, each of infinite height or depth, and which showed a remarkable analogy, both qualitatively and quantitatively, with the cyclonic waves as we know them from the meteorological charts. In only one point of importance was the theory incomplete—it seemed impossible to limit the infinite medium by a plane horizontal boundary surface, corresponding to the surface of the solid earth, along which the cyclones propagate. But during recent months, Professor Solberg has succeeded in overcoming this difficulty; the mathematical representation of the cyclonic wave now seems complete and appears to be in the best accordance, both with the elementary theory developed in an earlier chapter of the book and with the conclusions drawn from the meteorological charts.

#### GENERAL CIRCULATION OF THE ATMOSPHERE

In the course of time, many theories have been advanced for the general circulation of the atmosphere, all more or less unsatisfactory. As a rule, symmetry around the axis of the earth has been supposed, but with the



consequence that two contradictions presented themselves—no distribution of pressure could be imagined, which made these systems of circulation agree with the gradient wind law; and the circulation in the extratropical latitudes had to go against and not with the thermal effect. As pointed out in previous reports, J. Bjerknes, H. Solberg and, later, T. Bergeron, suggested new systems in which the symmetry was given up, and which represented a step forward, without being fully satisfactory. But now J. Bjerknes gives in Chapter 17 of their book a system which may be conclusive.

It would lead too far to give a complete description of his theory, but a few essential features are these: there is a cellular division of the permanent circulations, not unlike the cellular division of waves, referred to in these reports. Just as in the waves, the cells are very flat. At low latitudes we find, on each side of the equator, one series of cells, of which the circulation in projection upon the earth is anticyclonic (the permanent or semipermanent anticyclones of the subtropics). The cells are separated from one another by inclined surfaces of discontinuity, all sloping toward the east, the angle of slope being of the order of magnitude of  $1/100$ . Within the cells, the particles of air run in closed paths contained in inclined surfaces which are sloping eastward, the angle of slope being of the order of magnitude of  $1/1000$ . In the extratropical latitudes we meet with a similar set of cells in which the circulation in projection upon the earth is cyclonic (the semipermanent cyclones of the mean latitudes). The inclined surfaces of discontinuity separating these cells from one another have their slope toward the west, and the same is the case with the surfaces containing the paths of the particles, the order of magnitude of the angles of slope being again about  $1/100$  and  $1/1000$ .

This system of circulation gives a course of the isobars which is possible on the rotating earth; both cyclones and anticyclones become positively working thermodynamical engines; the entire system gives a close agreement with the average conditions of the atmosphere; the modifications of the system by geographical conditions are easily seen; and the relation of this semipermanent system of circulation to the atmospheric disturbances and to the "weather zones" is very clear, as shown in the last two chapters of the book.

The four authors are highly indebted to Mr. C. L. Godske for very helpful assistance in all parts of the book.

## NUTRITION

Mendel, L. B., and H. B. Vickery, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-30.)

The extensive comparisons that we have made, during recent years, of the morphological features of rats of our long-established strain under conditions that result in growth at widely different rates were discussed in some detail in last year's report. Further data secured by Dr. Gairdner B. Moment indicate that the size (weight) of the heart, three selected muscles, the kidneys, the liver, the spleen, the thyroid and the pituitary is related to the weight of the animal rather than to its rate of growth or age. Comparative histological study of these tissues failed to indicate any departure from normality referable to the different rates at which the size of the organs examined was attained. This does not apply, however, to the thymus nor to the eye. The maximum size and the rate of involution of the thymus appears to be a function of age rather than body size, and there is also evidence that the growth of the eyeballs is related to age rather than to the rate of growth. Rats that grew rapidly to a body weight of 420 grams had smaller eyes than animals that had grown more slowly to the same weight. Rats that grew rapidly to a body weight of 420 grams, and were then maintained at this size until a similar weight had been attained by companion animals that grew much more slowly, had eyes of the same size as these. It is clear, therefore, that the eyes continued to grow long after the rest of the body had ceased to increase in weight.

Incidental chemical examination of the bones of apparently healthy rats that had been grown upon rations of different composition with respect to the inorganic constituents showed considerable variation in the mineral (ash) content of the osseous structures in otherwise apparently comparable animals. These animals, despite a similar healthy appearance in every obvious external respect and a strictly similar rate of gain over long periods of the growth cycle, were notably *unlike* when judged on the basis of a comparison of the chemical composition of their skeletons (*cf.* records for rats on 1 per cent and 4 per cent salt mixtures in the following table). The implication is that there are tissues that may not attain their highest, or their optimal, content of some important, chemical constituent under conditions that seem to produce normality in other structures. Thus a seemingly well-nourished animal of proper body build may lack the optimal composition in some of its organ systems.

These observations have given rise to an extensive research involving chemical studies of selected tissues from rats on otherwise strictly comparable diets, but for which the levels of intake of a number of commonly used inorganic salt mixtures were widely varied. An outline of a typical experiment follows:

Groups of ten male rats, aged 21 to 32 days and weighing 37 to 56 grams, were selected for the feeding tests. The individual rats were killed.

and examined on attaining a weight of 200 grams. The rations consisted of casein 18, butter fat 9, lard 20, yeast 8 per cent, together with Osborne-Mendel salt mixture IV as indicated in the table, the balance of the diet being made up with starch. A supplement of 10 drops of cod liver oil was administered daily.

Salt mixture added	Average ash content of fat-free, water-free femora	Average time required to increase in body weight from 60 to 200 grams
Per cent	Per cent	Days
0.5	46.08	43
1	47.11	31
2	56.49	34
4	61.87	32
10	62.90	32
15	62.98	35

Similar comparisons are being made in an elaborate way for a number of the salt mixtures that are being used extensively in different laboratories. Several outstanding observations have already been made. There is a maximum as well as a minimum salt intake above or below which, respectively, growth, as exhibited by rate of gains in weight, is delayed or, in the extreme limits, actually stopped. Between such limits there may be comparable somatic growth despite considerable variations in inorganic salt intake. This is in harmony with the unique capacities of the living organism to dispose of unneeded inorganic ions. Too much of the latter in the diet seems to interfere with proper food intake, as one might expect. Too low a salt intake leads to stunting of growth, such as a shortage of any dietary essential entails. When the lacking ingredients are bone-forming elements, the skeletal structures and teeth suffer so that various secondary or consequent malformations of the body may be developed. The manifold effects of such "perverted" growth can not yet be foretold. Some of them, notably changes in the skull and the eyes, are being investigated.

In the case of several of the salt mixtures, including the Osborne-Mendel IV mixture, improvement in growth was readily secured by supplementation of the diets, in which the lower (0.5 per cent) levels of inorganic nutrients were fed, with a source of calcium (calcium carbonate). This indicated clearly that the latter element is the most conspicuous limiting factor in respect to growth and normal bone composition under the conditions cited. The composition of the blood (hemoglobin content) was not altered by such supplementation. Other additions are being made to the diets upon which growth is impaired by the low content of mineral nutrients in the otherwise satisfactory ration. The studies still in progress indicate that probably none of the inorganic mixtures in common use in feeding animals is "ideal" in composition. When these are fed in sufficient abundance, the relative shortcomings do not come into play; it is only when the body is forced to deal

with minimal intakes that the advantages of the better mixtures become emphasized. The goal of such experimentation is to devise dietary salt mixtures in which the essential elements are in the best relative proportions; the intake may then be reduced considerably. As a by-product of the research, an unexpected variety of pathologic conditions induced by factors not primarily represented by calories, proteins, nor vitamins have been observed.

The latest study on rapid growth of the albino rat, carried out in our laboratory by Professors Arthur H. Smith and W. E. Anderson, has been completed and a statistical summary of the data published. The average growth of 21 unselected individuals has exceeded all known records for rapid development in this species when no stimulants other than those properly constituting the food are employed. The striking feature of these observations is the continuation of the rapid rate of growth beyond that period when rapid increments in body weight ordinarily cease. Thus the rate of gain from 60 to 200 grams body weight for this group of rats was 6.1 grams a day; from 60 to 300 grams was 6.0 grams a day, and from 60 to 400 grams, 5.2 grams a day, and only 2 individuals had ceased to contribute to this last average. Anderson and Smith state further that—

“Whereas it appears that the circumstances favoring a rapid rate of growth also induce a high maximum body weight, the data . . . lead to the conclusion that under the experimental conditions herein described, there is little, if any, correlation between weight at weaning and either rate of growth or maximum body weight attained.”

The investigation of the reproduction of the albino rat on an adequate, but somewhat limited, ration has been continued. The plan of the study was outlined in the last report and the record of the third generation of the progeny of the original animals is nearing completion. The extensive data obtained from the first and second generations have been partially summarized and warrant some tentative conclusions. On the basis both of fertility *per se* and of lactation, it appears that varying degrees of intensity of breeding exert little effect on the procreative ability of the females over a period covering four complete reproductive cycles. However, the data of the second generation indicate that, in those groups which were allowed only one week for rest between cessation of lactation and remating, there is a decrease in proportion of fertile matings as well as an increasing difficulty in rearing young from birth to weaning. These preliminary deductions raise the question as to the most favorable details of management of this valuable laboratory animal if it is to be restricted for long periods to the same ration, however adequate this may be from the point of view of modern nutritional standards.

In collaboration with Dr. Riddle and his associates at the Station for Experimental Evolution at Cold Spring Harbor, Long Island, we have made a study of the so-called “crop-milk” of pigeons. The young are fed with this substance by the parent birds for a short time after hatching. The content of crop-milk in protein, fat, ash and water was 18.8, 12.7, 1.6 and 64.3 per cent, respectively; the material therefore supplies approximately 190 calories per 100 grams. Feeding tests on albino rats have



demonstrated the presence of vitamins A and B (B+G) in relatively low concentration; 4 grams of crop-milk were about equal in anti-ophthalmic power to 1 drop of a good grade of cod liver oil, and 3 grams of crop-milk promoted growth at approximately the same rate as 0.1 gram of dried brewery yeast. When fed as a supplement to rats on an otherwise adequate ration, crop-milk is, therefore, a meager source of vitamins A and B (B+G); nevertheless the total quantity of these vitamins presented to the squab, which ingests crop-milk as its sole food, is relatively great. For example, a squab weighing 10 to 13 grams at hatching may ingest 3 to 4 grams of crop-milk the first day, 5 to 10 grams the next and 10 and 12 grams the following two days. The squab has then received the equivalent of 1 drop of cod liver oil and 0.1 gram of dried yeast on the first day, 1.5 to 2 drops of cod liver oil and 0.2 gram of dried yeast on the second day, and 2.5 drops of cod liver oil and 0.4 gram of dried yeast on the third and fourth days—a generous allowance of vitamins for so small a bird. Another source of vitamin A for the newly hatched pigeon is the pigeon egg yolk (demonstrated to contain appreciable quantities of vitamin A) which is folded into the gut at hatching. The liberal supplies of vitamins received by the squab through the daily ingestion of crop-milk are believed to contribute to the very rapid growth exhibited by these birds.

Details of our investigations of the nutritive properties of tobacco seed were reported in Year Book No. 30 (p. 434 ff.). The completed study—part of a general project involving the subject of “cell chemistry”—can now be summarized as follows.

Feeding trials on albino rats have shown that this species can be successfully raised to maturity at a satisfactory rate of growth, and can reproduce on a diet that consists almost exclusively of tobacco seed. Either 1 or 2 per cent of inorganic salts was added and a few drops of cod liver oil were administered daily. This was essential to successful growth because of the deficiency of the seed in vitamins A and D.

Experiments designed to provide evidence of the presence of vitamin A in the seed were somewhat inconclusive. It is certain that the seed does not contain a concentration of this vitamin adequate for successful growth nor for complete protection against xerophthalmia. It is probable, however, that the vitamin is not entirely absent.

Vitamins B and G were present in tobacco seed in quantities adequate for growth and well-being. Under circumstances in which unusual demands for vitamins B and G are made by the organism as, for example, during lactation, a moderate degree of deficiency was apparent.

Although no final conclusion can yet be drawn, it is probable that tobacco seed is almost, if not entirely, deficient in vitamin D.

Vitamin E is present in tobacco seed in quantities adequate to provide for reproduction and to protect both sexes from physiological changes due to a deficiency of this factor. Animals that have depended upon tobacco seed as their sole source of vitamin E have been reared into the third generation.

Experiments on mice and on pigeons have demonstrated the non-toxicity of the tobacco seed for these species; likewise the good nutritive value of

the proteins in the seed. The seed also supplied the water-soluble vitamins needed by mice, and functioned as an effective antineuritic agent (proof of vitamin B) for pigeons.

The success of these feeding experiments demonstrates that the total protein of this seed is of exceptionally good biological quality; in this respect it resembles the proteins of other oil seeds for which experimental data have been obtained.

A few experiments on young chickens showed that tobacco seed is not a satisfactory source of nutriment for this species.

During recent years considerable study has been devoted in this laboratory to the development of the methods for the determination of the basic amino acids that result from the hydrolysis of proteins. We reported last year on the application of these methods to the analysis of a series of keratinaceous tissues, such as human hair, wool and feathers, and on the interesting fact that the essential proteins of these tissues yielded proportions of the three bases that bear extraordinarily similar molecular ratios to each other. Three papers in which the results of this work are described have now been published. During the present year, we have applied the method to the analysis of egg albumin, a protein of great interest not only in human nutrition, but also from the standpoint of the fundamental physical chemistry of proteins. The work of Sørensen and of Svedberg has shown that properly purified crystalline egg-albumin represents a nearer approach to the ideal of a homogeneous chemical substance than does any other protein and it is, therefore, frequently employed in studies of the behavior of proteins in solution. Its usefulness has been restricted in the past, however, by the lack of accurate information regarding its amino acid composition. Our analysis, which was conducted with the assistance of Miss Agnes Shore, now of King's College, London, has shown that crystalline egg-albumin yields 1.42 per cent of histidine, 5.39 per cent of arginine and 4.97 per cent of lysine. These results are in close agreement with the assumption that the molecule of egg albumin, the weight of which is probably close to 34,000, contains 3 histidyl radicals, 11 arginyl radicals and 12 lysyl radicals.

Studies of the complex compounds that form when amino acids are treated with an excess of mercuric chloride and the solution is made faintly alkaline have been continued by Mr. W. G. Gordon of the Department of Physiological Chemistry, Yale University. It seems probable that these compounds may be of considerable value in analytical separations of the amino acids. Although the work has not yet proceeded far enough to permit of wide generalization, the complex compounds appear to be alkali, or alkaline earth, salts of a radical that contains 3 mercury and 2 nitrogen atoms together with 1 atom of chlorine. A considerable number of these salts have been prepared and the investigation is being continued.

We have been able, during the present year, to offer facilities for research to three holders of Sterling or Coxe Fellowships at Yale University. Although this has meant that, frequently, seven workers have been crowded into space designed to accommodate four, the results have been well worth the temporary discomfort involved. Fortunately the expansion of the

laboratory facilities projected for the coming year will prevent a recurrence of this.

Dr. W. F. Hanna, of the Dominion Rust Research Laboratory at Winnipeg, studied a chemical difference between two species of wheat smut, *Tilletia levis* and *Tilletia tritici*, that are frequently confused with each other. An odor resembling that of trimethylamine has often been reported as associated with the spores of these smuts but, in Dr. Hanna's experience, the odor is found only in the spores of *Tilletia levis*. He was able to isolate trimethylamine from aqueous extracts of the spores of *Tilletia levis*, and to identify it as the substance responsible for their characteristic odor. He further showed that none of this substance could be detected in similar extracts of the spores of *Tilletia tritici*. The observations were made on spores of both species that had been separately grown upon seven varieties of wheat at the Winnipeg laboratory. The method he employed was founded directly on the method developed by Vickery and Pucher for the determination of ammonia in the presence of nicotine, or amines, referred to in Year Book No. 28.

Dr. A. White has been engaged throughout the year on the development of a new method for the determination of cystine in proteins. This method is founded on the observation, made in this laboratory a few years ago, that cysteine can be precipitated from protein hydrolysates as a silver mercaptide. Further study has now shown that the cuprous mercaptide is, in some respects, more convenient to employ for this precipitation, and also that if the protein is hydrolyzed in the presence of tin the removal of cysteine is specific and practically quantitative. The use of cuprous oxide as a reagent was introduced by Sir F. Gowland Hopkins a few years ago in connection with his work on glutathione, and the cuprous compounds of other sulphhydryl compounds, including cysteine, have recently been obtained by Pirie. Our application of cuprous oxide to the analytical separation of cysteine provides a new example of the great value of this reagent since, for the first time, it is now possible to free hydrolysates of proteins from cystine. The value of such a procedure in the study of the nutritive properties of cystine is obvious, and many other applications, such as the investigation of cystinuric urine, readily suggest themselves.

The new procedure for the determination of cystine consists essentially in the precipitation of the cystine, that results from hydrolysis of the protein in the presence of tin, by means of cuprous oxide. The precipitate is decomposed and the organic sulfur in it is determined by standard methods. Our data indicate that it is possible to recover cystine added to proteins with an accuracy of approximately 93 per cent, which is probably the order of accuracy of most amino acid determinations. Determinations of cystine in several proteins have shown fairly close agreement with the results of the best colorimetric determinations.

Dr. B. W. Towne, of St. Bartholomew's Hospital, London, England, has studied the methods for the separation of amino acids by means of their copper salts, a problem in which he has been interested for some years. His work has shown that, with the exception of the isolation of proline for which this method seems admirably suited, the copper salt methods present no clear-cut advantages over the classical methods of Fischer.



Our work on the metabolism of green leaf tissue has progressed steadily throughout the year. Last year we reported briefly the results of a study of the chemical changes that occur during the curing of tobacco. In connection with that work it was found that the changes in the forms of nitrogen, and in the carbohydrates, proceed with extraordinarily great rapidity in the very early stages of the process. We have accordingly devoted considerable time this year to the investigation of the changes that occur during the first twelve days of curing. Samples of leaves of approximately equal initial weight were cured for one to twelve days and, parallel with these, equal samples were placed with their bases in water for a similar period of time. These samples therefore furnish material in which the chemical changes proceeded without desiccation of the tissue, and represent what may be termed a "starvation" experiment. Extracts of each of these two lots of samples have been prepared, and both extracts and tissue residues have been analyzed. The data have, at the present writing, been assembled but await study.

Dr. G. W. Pucher of the Station staff, and Dr. Wakeman have conducted an investigation of the acidic constituents of leaf tissue, particularly of tobacco leaf. In connection with this work the observation was made that nitric acid can be quantitatively extracted from leaf tissue by means of ether, provided the tissue is treated with a sufficient amount of sulfuric acid to bring its reaction to the vicinity of pH 1. This behavior of nitric acid, so far as we can discover, has been entirely overlooked in the past, but it provides an opportunity for the determination of nitrate nitrogen in plant tissue that is entirely free from many of the difficulties that are encountered with the currently used methods. Considerable study has accordingly been devoted to the phenomenon, and a highly accurate and widely applicable method for the determination of nitric acid in plant tissues, or in extracts therefrom, has been developed. It is described in a paper contributed to the *Journal of Biological Chemistry*.

The other acidic constituents of leaf tissue that are extracted by ether, along with the nitric acid, have also been investigated, and it seems probable that a method for the accurate determination of their total amount will likewise be found. This is a matter of great significance since the organic acids of the leaf are intimately linked with the metabolism both of proteins and of carbohydrates, and also play an important rôle in the system of buffers whereby the proper reaction of the leaf cells is maintained.

Dr. Pucher has continued his study of the organic acids of the tobacco leaf. The esters of the acids obtained from extracts of several large lots of leaf at different stages of curing have been prepared and distilled. The fractions that contain the better known constituents have been studied and attention is now being paid to the smaller fractions that contain material much of which is still of unknown nature. We hope to be able, when this work is completed, to trace the changes in the acidic constituents of the leaf throughout the period of curing, and to obtain some evidence of the fate of the large quantity of leaf protein that disappears as such and the nitrogen of which can be detected in the form of ammonia, or of amides, at the end of the curing process.



We have continued our cooperation with Dr. A. C. Chibnall of the Imperial College, London, England. An ether extract of a considerable quantity of fresh, dried tobacco leaf was prepared and sent him for analysis and comparison with the extract of cured leaf we prepared for him last year. Dr. Chibnall's methods for the analysis of plant lipids have now been fully developed and our cooperation with him is productive of great mutual benefit.

Two publications, the preparation of which was mentioned last year, have now appeared. Dr. Vickery's biographical memoir of the late Dr. Thomas B. Osborne, written at the request of the National Academy of Sciences, was distributed last November; and the extensive review of the early literature of the amino acids in the preparation of which Dr. Vickery collaborated with Professor C. L. A. Schmidt, of the University of California, was published in the October 1931 number of Chemical Reviews. During the current year an article on the nitrogenous constituents of green plants has been contributed to the Annual Review of Biochemistry, published by the Stanford University Press.

The following have served as assistants in the work: Alfred J. Wakeman, Ph.D.; Charles S. Leavenworth, Ph.B.; Elizabeth C. Callison, M.S. (half time to September 12, 1931); Lucille L. Reed, Ph.D. (from September 1, 1931); Laurence S. Nolan, technician; Luva Francis, secretary.

**Williams, R. R., and Walter H. Eddy**, Teachers College, Columbia University, New York, N. Y. *Physiological functions of the vitamins*. (For previous reports see Year Books Nos. 27, 29 and 30.)

This study has been made possible by means of a grant from the Carnegie Corporation of New York.

During the year we have been chiefly concerned with perfecting the process of isolation of vitamin B<sub>1</sub>, a field of effort in which there has been an unusual amount of activity in several other widely scattered laboratories.

Perhaps the most notable contribution was made by Windaus and collaborators late in 1931.<sup>1</sup> These workers reported the isolation from yeast, by a process essentially similar to that of Jansen and Donath,<sup>2</sup> of a substance of like physical properties to those of the vitamin obtained by the Dutch experimenters in 1926. The latter started with rice polish as a source. With respect to composition of this substance, Windaus *et al* made the startling observation that it contained sulphur, a finding wholly at variance with Jansen and Donath and with Van Veen,<sup>3</sup> who had made an extended series of chemical studies of the rice polish substance in the intervening years.

The physiological properties of the substances from yeast and rice polish appeared to be identical, and it seemed incredible that so large a discrepancy in composition could actually exist. This doubt was presently resolved by Tschesche,<sup>4</sup> one of Windaus' original collaborators who, by exchange

<sup>1</sup> A. Windaus, Nachrichten von der Gesell. der Wissenschaften zu Göttinger. 209, 1932.

<sup>2</sup> B. C. P. Jansen and W. F. Donath, Mededeel. Dienst Volksgezondheid Ned.—Ind. pt. 1, 186, 1926.

<sup>3</sup> A. G. Van Veen, Rec. d. trav. chem. d. Pays Bas, vol. 49, 1178, 1930; vol. 50, 200, 204, 208, 610, 1931; vol. 51, 265, 279, 1932.

<sup>4</sup> R. Tschesche, Zeit. Physiol. Chem., vol. 204, 123, 1932.

of material with Jansen, ascertained the presence of sulphur in both and convinced himself, by a mixed melting point determination, that they were identical.

Late in 1931 Ohdake,<sup>1</sup> following Jansen and Donath's procedure with rice polish, obtained a substance apparently identical with Jansen and Donath's but, like Windaus, he found sulphur present, leaving little room for doubt that the isolation of 1926 was genuine though obscured by an analytical error in overlooking sulphur.

However, a number of discrepancies still exist. The following empirical formulæ have been proposed:

Jansen and Donath, 1926.....	$C_6H_{10}N_2O$
Van Veen, 1931.....	$C_6H_{10}N_2O_2$
Windaus, 1931.....	$C_{15}H_{17}N_3O\ S$
Ohdake, 1932.....	$C_{12}H_{16}N_4O_2S$
Van Veen, 1932.....	$C_{12}H_{20}N_4O_2S$

There is a very fair agreement among the workers as to the melting point of the hydrochloride with values ranging from 245° to 250° C.; the melting point of the picrolonate ranges from 165° C. (Jansen) to 229° C. (Windaus). In respect to precipitation reactions the agreement among workers is good.

The reason for the discrepancies in composition no doubt arises from the very sparing quantities of material which have been available for final purification and analysis as a consequence of the extremely large losses in process of isolation. We have examined many specimens of rice polish of American origin and find that 1 gram of polish yields, upon thorough extraction with dilute alcohol, from 3 to 5 curative rat doses of vitamin, 4 doses being representative of good commercial material. The rat doses referred to are the amounts necessary to cure polyneuritis in rats according to the method of Smith.<sup>2</sup> This rat dose must be distinguished from Peters' "day dose" which is arrived at by dividing the curative dose for a pigeon by the number of days elapsing after cure before recurrence of the symptoms. However, the rat dose as used by Smith and ourselves is certainly, from our own experience, not less than the curative pigeon dose (in spite of a large difference in body weight). This has also been confirmed by prophylactic feeding tests on pigeons which show that 0.25 gram of rice polish will protect pigeons indefinitely against polyneuritis. We therefore calculate that rice polish contains about 4,000,000 doses per metric ton or from 20 to 40 grams of vitamin. Brewers yeast is even richer. The yields of crystalline product obtained by various workers are as follows:

Approximate vitamin available per ton....	40.0 grams
Jansen and Donath, 1926.....	.33
Van Veen, 1931.....	1.30
Ohdake .....	.14

Windaus' yields from yeast are, evidently, of similar magnitude.

The losses in process are from two causes. In the early stages scattering occurs in the various large discards, particularly the extracted rice polish

<sup>1</sup> S. Ohdake, Proc. Imp. Acad. Tokyo, vol. 7, p. 102, 1931.

<sup>2</sup> M. I. Smith, U. S. Pub. Health Repts., vol. 45, 116, 1930.

and the baryta extracted Fuller's Earth. In the later stages, loss occurs primarily by conversion into inactive products by chemical reactions which appear to involve oxidation or dehydration or both. We have long recognized the imperative necessity for vast improvement in yields and adaptation of the process to large scale factory type of operations.

In order to accomplish these results we extracted two tons of polish during the past winter in two lots of one ton each. One ton of polish was suspended in approximately 4000 liters of 15 per cent methyl alcohol and the mixture acidulated with sulphuric acid to pH 4.5. After 12 to 16 hours stirring, the polish was allowed to subside. From 48 to 72 hours was necessary to develop a layer of clear liquor of 2000 to 2500 liters which could be pumped off into an adjacent tank where it was stirred with 30 kilos of Fuller's Earth. After allowing the Fuller's Earth to settle, the supernatant liquor was transferred back to the rice polish tank. Stirring, settling and removal of the clear liquid was repeated in this way a total of four times.

This experience demonstrated a defect in the method, namely, that large losses of alcohol occur by evaporation, and bacteriological decomposition is extremely liable to occur during the long periods of extraction and settling which are involved. We believe that this difficulty can best be overcome in the future by using four or five times as large a ratio of liquid to polish, in which case subsidence is much more rapid and a single extraction may be expected to remove a proportionately larger part of the activity. The cost of alcohol would be excessive and another preservative must be found. We have had some favorable results by the use of a layer of toluene on water.

In the two-ton experiment mentioned, we obtained 60 kilos of activated Fuller's Earth containing only about two million doses as compared with eight million in our source material. Not more than one-fourth of the loss could be accounted for in the spent polish.

We have referred in our previous report to the loss of approximately 50 per cent of the vitamin which occurs in extracting activated Fuller's Earth with baryta. Accordingly, we used hot 5 per cent quinine acid sulphate solution as a substitute for baryta. By digesting 30 kilos of the Fuller's Earth with 150 liters of this solution and filtering and repeating this operation two more times, we obtained an extract which after removal of the quinine was found to contain the whole of the vitamin within the limits of experimental error. The sole serious defect of this process is the expense of the quinine which, however, can be recovered and reused to a great extent though not without considerable labor and cost for solvents, etc.

The quinine was removed largely as sulphate by neutralizing the solution with sodium hydroxide. At this point we again departed from the precedents of the literature by precipitating the solution with an excess of methyl orange.<sup>1</sup> This reagent forms sparingly soluble salts with a great variety of nitrogenous substances and is an excellent clearing agent for dilute vitamin solutions (50 doses per c.c. or less). The precipitate of helianthates was recrystallized from hot water and the mother liquor combined with the

<sup>1</sup> C. R. Stark, and W. M. Dehn, Jour. Amer. Chem. Soc., vol. 39, 1378, 1917.



main filtrate. The combined liquors showed no measurable loss of activity in this step.

We now applied mercuric acid sulphate as a clearing agent as had been previously done by Peters and Windaus. Unfortunately, due to the difficulties of control of large scale operation (800 liters at this stage), a greater excess of mercuric acid sulphate was added than necessary. The filtrate from the mercuric acid sulphate was treated without removal of mercury with 8 kilos of Fuller's Earth to absorb the vitamin. On removal of the vitamin from this Fuller's Earth, we found that mercury was still present in the extract and a loss of approximately 80 per cent of the vitamin had occurred.

We are inclined to ascribe this large loss to oxidation by mercury, a point which will be discussed further. We had repeatedly carried out this operation on a small scale with very satisfactory recovery but presume that partly on account of the presence of excess mercury and partly on account of the long duration of the large scale operations, destruction occurred in the latter case. Separation of metallic mercury was noted.

We will not extend further the account of this particular large scale operation but will now turn our attention to the subject of losses which we have found to occur in late stages of isolation.

In addition to the well-recognized destruction by alkali in such steps as baryta extraction of Fuller's Earth or decomposition of phospho- or silicongstates there are several other pitfalls to be avoided. Jansen and Donath have remarked the destruction by alcohol acetone fractionation of the hydrochloride. This action appears to be due primarily to the dehydrating effect of absolute alcohol. Heating strong alcoholic solutions of the vitamin is accompanied by substantial losses and the accumulation of products which are very sparingly soluble in absolute alcohol.

Heating with strong hydrochloric acid is also destructive, a fact which has been noted by Van Veen.<sup>1</sup>

Windaus has referred to the fact that the vitamin gold double salt darkens on standing with separation of free gold. We have also noted this phenomenon to such an extent that the activity of the gold double salt was completely lost on standing for 48 hours. Although a substantial part of the activity can be recovered if the gold salt is promptly decomposed with hydrogen sulphide, losses of approximately 50 per cent are inevitable in our experience. On this account and also because in the case of rice polish the gold salt does not come out in crystalline form as described by Windaus in the case of yeast, we do not regard this reagent as at all satisfactory.

The destruction of the vitamin in the same way occurs when it is converted into the platinum salt.

In view of these cases of destruction by mercury, gold and platinum clearly indicating an oxidative action, we have often suspected atmospheric oxidation as a destructive factor. We, however, were unable to confirm this by exposing solutions of relatively pure vitamin (0.05 mg. per dose) to oxygen under 200 pounds pressure for 36 to 48 hours at pH 3, 5 and 7. No measurable destruction occurred. It is also well known that vitamin

<sup>1</sup> A. G. Van Veen, *Zeit. Physiol. Chem.*, vol. 208, 125, 1932.



solutions can be subjected to vigorous oxidizing agents such as nitric acid, hydrogen peroxide or permanganate without appreciable loss.

Our experience with picrolonic acid as a reagent in obtaining the vitamin in crystalline form is not reassuring. Picrolonic acid itself easily undergoes decomposition; it is not selective as a precipitant for the vitamin and the reagent is so sparingly soluble that it often separates with or in advance of the vitamin picrolonate upon concentration of a solution. There is great need for a better reagent for this purpose and a search for it is actively under way. All the usual alkaloidal reagents have been tried by various workers and it will be necessary to depart from the beaten paths. Some promising results have been obtained with novel reagents on which it is too early to report at present.

The object of the investigation continues to be the isolation of the vitamin in liberal amounts for constitutional study.

We have continued to enjoy during the year the cooperation of Messrs. Robert E. Waterman, Samuel Gurin and John C. Keresteszy in the chemical procedures, and of Misses Marion Ammerman and Minerva Kellogg in the care and treatment of experimental animals.

## PALEONTOLOGY

**Carpenter, F. M.,** Museum of Comparative Zoology, Cambridge, Massachusetts. *Investigations of fossil insects.*

The investigations carried out under the grant from the Carnegie Corporation of New York during the previous year, such funds having been made available through Carnegie Institution of Washington, were mainly concerned with the continuation of a revision of the Lower Permian insects of Kansas. Part 5 of the series of papers, devoted to the Psocoptera and additions to the Homoptera, is in press; parts 6 and 7, on the Delopteridæ and Protelytroptera, are ready for publication; and parts 8 and 9, on the Neuroptera and Protoperlaria, are nearly complete. A descriptive account of the Jurassic insects from Solenhofen, contained in the Carnegie Museum and the Museum of Comparative Zoology, is also in press. Three months were spent in the field, resulting in the collection of over two thousand Permian and Carboniferous insects from Oklahoma and Kansas. These new fossils will be studied at the Museum of Comparative Zoology during the coming year.

**Merriam, John C., and Associates.** *Continuation of paleontological researches.* (For previous reports see Year Books Nos. 20-30.)

Researches on the history of life conducted in the past year may be classified as follows:

1. Detailed investigations on special problems, including the securing of new data and their intensive study along with reorganization of materials already available.

2. Aid in furtherance of investigations by Research Associates whose studies are closely related to those involved in the problems upon which work has been undertaken by Mr. Merriam.

3. Cooperation with investigators whose researches in various subjects extend our knowledge of problems on which studies are conducted under auspices of the Institution.

4. Development of means for effective interpretation of problems concerned in the researches now under way. These activities have been designed both to make clear the results of investigations and to stimulate much needed research on the subjects considered, as also in related fields.

Intensive research on special problems noted under item one has concerned mainly Pacific Coast questions upon which investigations were initiated by Mr. Merriam at the University of California. These include completion of studies on the fauna of Rancho La Brea, on several problems concerning evolution and distribution of mammalian faunas of the later geological periods, and on further development of a correlation paper covering history and distribution of life in the Tertiary and Quaternary periods of the Great Basin Province of America. The correlation paper constitutes a synthesis of knowledge on the paleontology and geology of the last two geological eras for a region situated between the Sierra and Wasatch ranges,

and extending south from eastern Washington to the Gulf of California. As a further problem, careful examination is being made of investigations in vertebrate paleontology on the Pacific Coast of North America, with a view to determining what constitute major research questions of this field for which materials in the region furnish exceptional opportunity.

Advance of paleontological investigation by Research Associates of the Institution ranges over a group of subjects the development of which is essential for furtherance of problems considered under item number one. These contributions extend into related fields which have great importance in study of the history of life. Among these studies is the work of John P. Buwalda, Chester Stock and E. L. Furlong, at California Institute of Technology, concerned with major problems in geology and paleontology of the last three geological eras. Especially important are their investigations in the John Day region of eastern Oregon, on late faunas of southeastern Oregon, southwestern Idaho, Nevada, and a number of localities in California. Reports on these studies are made in separate statements following this outline. A recent publication on work by E. L. Furlong relating to evolution of the antelope group in America marks an important advance in our knowledge of this interesting problem.

Investigations have been continued by Remington Kellogg extending his large contribution to history and evolution of marine mammals including the whales, seals and sea-cows. These researches take high rank among studies on modification of structure in land animals which have become accommodated to life in the sea. Separate statement of the work of Dr. Kellogg follows this report.

The researches of Ralph W. Chaney on the history of plants have continued as one of the outstanding contributions of America in this subject. Recent studies have broadened the program of Dr. Chaney for placing paleobotanical research in this particular field on a basis comparable to that in other aspects of paleontology. Dr. Chaney has extended his studies to include classification and distribution of present-day plants through further examination of floras of North America and Asia, and by field work on distribution and association of floras of southern United States, Mexico, Central America and South America. This comparison of materials illustrating evolution and distribution in plants of today has illuminated in a most extraordinary way the history of plants on the Pacific Coast. A separate report by Dr. Chaney appears in the Report by the Division of Plant Biology.

Investigation of the extremely early plant life of Algonkian rocks in the Grand Canyon region by Dr. David White is one of the most important studies on the history of plants under way in America. The monograph in preparation by Dr. White will be supplemented by material on the occurrence of these plants secured by field work of N. E. A. Hinds at the Grand Canyon.

In cooperation with investigators of other institutions, as described in item three, extremely important results have been obtained through researches on the paleontology of eastern Oregon guided by E. L. Packard; and by investigations on problems of the Grand Canyon carried out in co-

operation with National Park Service. Dr. Packard's contribution on faunas of the Cretaceous period is of great significance in the history of life in the Pacific Coast region. Discovery by Dr. Packard and his associates of a series of faunas extending into the Paleozoic era is one of the most significant contributions of the past decade in the paleontology of the northwest.

Researches at the Grand Canyon include cooperation in eight groups of investigations, ranging through the history of life and its environment in that region. Edwin D. McKee, of National Park Service staff at Grand Canyon, has contributed in many ways to advance of this work, and has himself conducted studies of much value.

Research on statement and interpretation of major problems in the story of life, listed under item four, has been designed to present illustrations in nature sufficiently impressive to stimulate interest in research and educational problems in this field. These investigations have been conducted principally at the Grand Canyon, in cooperation with National Park Service, and under auspices of a committee of the National Academy of Sciences. Report on these activities will be presented in a later statement.

#### *Researches by John P. Buwalda*

A brief visit to Oregon and Washington in the fall of 1931 gave opportunity to gain further data on certain questions relating to the physiography and later history of the John Day region and to examine certain unexplored sections of the Ellensburg formation for data indicating origin and to search for fossils. The latter effort, successful only to the extent of a few additional fragments, relates to a paper on the age of this formation now in preparation by Dr. Merriam and the writer.

Knowledge of the stratigraphy, structure and history of the Indio region, in the Coachella Valley portion of the Salton Basin, was advanced during short excursions into this area during the winter, and it is hoped that this study may be completed during the coming winter months.

Mapping of the very complicated fault structure and of the Tertiary formations along both sides of the San Andreas fault in the Tejon Pass region was carried forward in the spring of 1932.

In order to test the effectiveness of the reflection and refraction methods of seismic prospecting for oil structures, and to appraise their possibilities for determining obscure geological structures in general, arrangements were made with Geophysical Service Inc., of Dallas, Texas, for the transfer to Southern California of one of its parties and equipment for experimentation during the summer of 1931. The investigation was supported by a special grant of funds by the Institution, and was made under the general supervision of Dr. Arthur L. Day. The writer, in association with Messrs. B. Gutenberg and H. O. Wood, aided in planning the different structural problems on which the methods were tested and spent considerable time in the field during July and August participating in the field studies and observing methods and results. The areas in which measurements were made were the Los Angeles Basin, the Ventura Basin, Yosemite Valley and Owens Valley, all in southern and central California. Among the problems attacked were the tracing underground of boundary surfaces between different types of rock, thickness of members in a sedimentary section, structure in a sedimentary area covered with a mantle of alluvium, velocity of earth



waves in different rock types including granite, possibility of eliminating surface waves in a record by detonating on one side of a gorge and recording on the other, detection of faults and thickness of the granitic layer or outer earth shell. Since the results of the researches are being published in the September 1932 Bulletin of the Seismological Society of America it is unnecessary to restate them here, but it may be of interest merely to indicate that the conclusions reached were that the methods constitute a powerful if somewhat elaborate tool for the determination of obscure geologic structures.

*Researches by Chester Stock*

Principal attention has been given this year to the completion of the research of the Felidæ of Rancho La Brea, conducted jointly with John C. Merriam, and to the several tasks attendant upon bringing the memoir to the stage of final printing. Certain phases of the problem of differentiation within the group of cats were presented during Exhibition Week of the Institution in December 1932.

Establishment of Cenozoic mammalian faunas for western North America has been facilitated during the past year by more intensive field exploration and development of particular localities. This work has been carried on in cooperation with the California Institute, and those immediately concerned with the paleontological problems are Chester Stock, E. L. Furlong, C. Lewis Gazin, Francis D. Bode and Robert W. Wilson. Mr. Furlong completed the study of the other material from the Pliocene Thousand Creek beds of northwestern Nevada, results of which are published in Carnegie Institution of Washington Pub. No. 418 (93-104, 2 pls.). The important contribution by C. Lewis Gazin on the middle Miocene mammalian fauna from Skull Spring, Malheur County, Oregon, has likewise appeared (Pub. No. 418, 37-86, 6 pls.) The Tecuya beds, furnishing a significant record of lower Miocene or upper Oligocene mammals of the Californian region, have yielded additional material, described by Chester Stock in Publication No. 418 (87-92, 1 pl.). A statement concerning Rancho La Brea has also been prepared for the Guidebook on Southern California to be published by the U. S. Geological Survey for the XVIth International Geological Congress.

Francis D. Bode has conducted for several years an intensive investigation of the middle Miocene mammalian fauna obtained in the Merychippus zone of the North Coalinga district, California. Mr. Bode has now completed a report on the anchitheriine horses from this horizon. Robert W. Wilson is completing a study of the Pleistocene mammals from the Carpinteria asphalt and has been concerned with the important ecologic aspects of this problem.

Valuable services have been rendered by the artist, John L. Ridgway, in the preparation and supervision of the illustrative material for the several paleontological reports.

*Researches by Remington Kellogg*

The investigation of the zonal occurrence of pelagic mammals in the Calvert formation of Maryland was continued. Included among the paleontological material obtained during the past season are skeletal remains belonging to a sirenian (*Metaxytherium*), three long-beaked porpoises (*Schizodelphis*, *Rhabdosteus* and *Eurhinodelphis*), and a rather large whalebone whale (*Cetotherium*).

In connection with the above investigation, field studies on the areal

distribution of the Calvert formation in southern Maryland have been undertaken in cooperation with Dr. A. Lincoln Dryden. One of the most important results of the past season's work has been the location of the area and the determination of the zones of the Calvert formation from which the type specimens of most of Cope's fossil cetaceans were obtained. Cope stated that his specimens "were collected by James T. Thomas near his residence in Charles County, Maryland, not far from the Patuxent River, in the beds of the Yorktown epoch, in places where they are exposed by the cutting of various streams." The residence of James T. Thomas is now owned by Mr. Stanley Birch and is located in Charles County on the road that leads to Benedict, about 2 miles east of Hughesville. Several localities were visited in this area, most of them about 1 mile east of the Patuxent River.

The description of one Miocene porpoise (*Argyrocetus joaquinensis*) from the Vedder zone of the Vaqueros formation near Bakersfield, California, was completed during this period and a study of other fossil porpoise material from the slightly younger Temblor formation of the Bakersfield region has been undertaken.

The report on the North American Archæoceti is well advanced.

Illustrations for the reports completed and in progress have been prepared by Sydney Prentice.

## PHYSICS

Compton, A. H., University of Chicago, Chicago, Illinois. *Studies of cosmic rays.*

### INITIATION OF THE PROGRAM

Though support of our cosmic ray studies has been given by the Carnegie Corporation of New York, through the Carnegie Institution of Washington, only since December 1931, our active work in this field had started more than a year earlier. The grant made by the Corporation has, however, made possible a much more extensive and thorough study of these rays than could otherwise have been attempted.

The objectives of this cosmic ray program were given as (1) to make a survey of the intensity of the cosmic rays over representative portions of the earth; (2) to study the rate of variation of cosmic ray intensity with altitude; (3) to study further the diurnal variation of the cosmic rays.

From the information thus obtained it was hoped to learn more definitely regarding the nature and the origin of the rays.

### PERSONNEL

The projected studies have met an enthusiastic response by all who were invited to join the work. For the world survey, the globe was portioned into nine regions, each of which has been assigned to a different investigator. By February first (1932) all of those asked to take charge of these various portions of the work had agreed to do so, and the construction of the seven identical sets of apparatus necessary for its completion was well under way. The nine men taking charge of the various aspects of the work are:

1. Arthur H. Compton, Professor of Physics, University of Chicago: Hawaii, New Zealand, Australia, Panama, Peru, Mexico, Canada.
2. Ralph D. Bennett, Associate Professor of Electrical Engineering, Massachusetts Institute of Technology: Alaska, California, Colorado.
3. Ernest O. Wollan, Instructor in Physics, University of Chicago: Spitzbergen, Norway, Switzerland.
4. Dr. D. LaCour, Director Danish Meteorological Survey: Copenhagen, North Pole of Earth's Uniform Magnetization, near Cape York.
5. Allen Carpe, Research Engineer, Bell Telephone Co.: Mt. McKinley, Alaska.
6. James M. Benade, Professor of Physics, Punjab University: India, Ceylon, Java, Himalayas.
7. S. M. Naudé, Professor of Physics, University of Capetown: South Africa.
8. Paul G. Ledig, Observer in Charge, Carnegie Magnetic Observatory, Huancayo, Peru: Southern South America.
9. Admiral Richard E. Byrd, Polar Explorer: Antarctica.

Each of these leaders was to have with him one or more assistants.

### PROGRESS OF THE STUDIES

The first of these expeditions started its work on March 18, and at the present writing (Aug. 1932) all are at work except Nos. 5, 8 and 9. The work of expedition 5 was terminated by a tragic accident, as will be re-

ported below. Expedition 8 expects to leave Peru about December 1932. Expedition 9 has been postponed for a year, due to other business requiring Admiral Byrd's attention; but his physicist, Professor Poulter of Iowa Wesleyan College, is ready to start work with the cosmic ray apparatus.

As yet only fragmentary reports are available regarding the scientific data obtained by the various branches of the expedition. Group 1, under Professor Compton, has sent two preliminary reports to *The Physical Review*, the contents of which are summarized below. Group 2, under Professor Bennett, reports successful readings at three stations in Alaska and one in California, with other work in progress. Dr. Wollan has had no opportunity to return a report, since his expedition did not leave Chicago until July. Mr. Carpe's records show data which should be a valuable addition to those secured by Professor Bennett. Nothing has as yet been heard from Professor Benade, except that his measurements were started in June. He is now in Thibet, attempting measurements on a high mountain in the Himalayas. Professor Naudé has reported progress with his measurements. From these fragmentary reports it is, however, evident that the world survey of the cosmic rays is rapidly being completed.

#### SCIENTIFIC RESULTS

*Dependence on Earth's Magnetic Field*—The preliminary reports made to the *Physical Review* by Professor Compton's party show that the information already gained has solved one important question: The cosmic rays do depend upon the earth's magnetic field, being stronger near the magnetic poles than at the Equator. When this survey was started, scientific opinion was divided on this point, favoring, however, the contrary view that the rays were of uniform intensity over the earth's surface. This discovery presents strong evidence in favor of the view that the cosmic rays are streams of electrified particles such as electrons or protons.

*Increase of Intensity at High Altitudes*—A second finding is that the intensity of the cosmic rays continues to increase with increasing altitude up to very high elevations. This conclusion is based on several series of mountain measurements, including one on El Misit, in Peru, at 19,150 feet. This result served to show that Piccard's 1931 balloon data were more reliable than those of Millikan in 1925, and has more recently been confirmed by the newly announced balloon measurements made by Regener. These high altitude data remove what has been considered a strong argument for the photon nature of cosmic rays, based upon the supposed fact that at high altitudes the intensity of the cosmic rays passes a maximum and becomes less as the limit of the atmosphere is approached.

*Bursts of Ionization*—Evidence showing that an individual cosmic ray is capable of releasing at least  $10^8$  electron-volts of energy has been found in the observation and measurements of bursts of ionization stimulated by the rays. Similar observations have recently been reported by Steinke in Germany. The present work has, however, given more detailed information regarding the nature, origin and significance of such ionization bursts.

*Diurnal Variation*—Bennett, Stearns and Compton have published a joint paper describing their measurements of the diurnal variation of cosmic ray intensity, made on Mount Evans, Colorado, during the summer of 1931.



In this paper a definite variation is noted, larger than that found by other observers at lower altitudes. The existence of this diurnal variation, and its greater magnitude with increasing altitude, has been confirmed independently by work done this summer by Bennett's and Compton's parties.

*Large Effects in Argon*—At the beginning of our work with the help of Carnegie funds, we discovered that argon gas under pressure is a much more sensitive detector of cosmic rays than other gases which have been tried. A study of the properties of argon gas has accordingly been submitted to the Physical Review by A. H. Compton and J. J. Hopfield, who assisted him with these experiments.

#### PUBLICATIONS

The following papers dealing with cosmic rays have been published or submitted for publication by our group during the past year:

A. H. Compton, R. D. Bennett and J. C. Stearns, *Ionization by penetrating radiation as a function of pressure and temperature*, Phys. Rev., vol. 39, No. 6, Mar. 15, 1932.

R. D. Bennett, J. C. Stearns and A. H. Compton, *Diurnal variation of cosmic rays*, Phys. Rev., vol. 41, No. 2, July 15, 1932.

A. H. Compton, *Variation of the cosmic rays with latitude*, Phys. Rev., vol. 41, No. 1, July 1, 1932.

A. H. Compton and J. J. Hopfield, *Use of argon in the ionization method of measuring cosmic rays*, Phys. Rev., vol. 41, No. 4, Aug. 15, 1932.

A. H. Compton, *Progress of cosmic ray survey*, Phys. Rev., vol. 41, No. 5, Sept. 1, 1932.

R. D. Bennett, *The riddle of the cosmic rays—how it is being attacked in a world-wide survey*, Tech. Rev., vol. 34, No. 9, July 1932.

Summarizing this aspect of the report, it may be said that the major scientific objectives set for the present date have been accomplished in a more thorough manner than had been hoped for when the work was undertaken.

*Death of Three Men*—We are grieved to report that three men have lost their lives while carrying out these studies, one of them the leader of one of our expeditions.

Mr. Allen Carpe and Mr. Koven died while making cosmic ray measurements on Mount McKinley. They were a part of an expedition which had as its objective climbing the peak of Mount McKinley. While the rest of the party were going to the summit, these two remained at the Muldrow Glacier to make their cosmic ray measurements. When the climbing party returned, the camp was deserted, Koven's body was found near a crevasse a mile away, and Carpe could not be found. It is surmised that he may have fallen into a crevasse while searching for Koven. Carpe's notebook was recovered, and contains data which are probably of value. Everything possible was done at the time, including searching by means of airplanes. At this writing there is a party, sent by Mr. Koven's relatives, on Mount McKinley to recover whatever apparatus is possible.

The third death is that of a guide on Professor Naudé's expedition near Capetown. We have no information other than a very brief news report of the incident.

**Compton, Karl T.**, Massachusetts Institute of Technology, Cambridge, Massachusetts. *Research in high vacuum spectroscopy*. (For previous reports see Year Books Nos. 28-30.)

These studies have been continued under a grant from the Carnegie Corporation of New York to Carnegie Institution of Washington.

Work of construction and adjustment was continued in the Palmer Physical Laboratory at Princeton University until February 1932, at which time the vacuum spectrograph and accessory equipment were transferred to the new Spectroscopy Laboratory of the Massachusetts Institute of Technology. At the same time Dr. Joseph C. Boyce, who has from the beginning of this work been associated with me, took up his new position at Massachusetts Institute of Technology as Research Associate in the Department of Physics, and is continuing his association with me in carrying out the program of research in vacuum spectroscopy.

During the late fall and winter the sources of leakage in the vacuum system were finally eliminated and a series of spectrum photographs were taken with a wide variety of types of gas discharge in order to learn the spectral characteristics of each type and to determine which could most advantageously be used for the enhancement of any given type of spectrum. This preliminary survey has been fairly well completed.

During the month of January the spectrograph was used in collaboration with Professor Ladenburg and Dr. C. C. Van Voorhis in a study of the absorption spectrum of molecular oxygen. Several fine sets of photographs were obtained which enabled accurate knowledge of the absorption of oxygen to be extended from its previous limit of 1300 Angstroms down to 300 Angstroms. These results were described in a letter to the Physical Review (vol. 40, p. 1018, June 15, 1932). A densitometer study of these plates was used to determine the constants in the Ladenburg dispersion formula and confirmed conclusions which had theoretically been drawn regarding the classical relation between absorption and dispersion, heretofore verified only for monatomic gases.

In addition to the results described in this letter to the Physical Review, the spectrograms gave further evidence of the prominent part which very short wave-length light may take in the phenomena of electrical discharge through gases and confirm the existence of a previously suspected region of relative transparency of air near 1200 Angstroms. On the basis of this transparency and the photoelectric effect of this radiation on electrodes, it has been possible to explain certain phenomena in Geiger Counters observed by Cooksey and Henderson and reported by them at the June (1932) Meeting of the American Physical Society.

Just as the spectrograph had been reassembled and was about ready for use in the laboratory at Massachusetts Institute of Technology, a fire from acetone used with carbon dioxide as a refrigerant destroyed the glassware of the main pumping system, so that this has had to be reconstructed. In the reconstruction, advantage has been taken of the development of the new "Aristovac" vacuum pump developed by the Central Scientific Company, which has been substituted for the previous mercury diffusion pumps so as to eliminate difficulties from mercury vapor and the necessity for the

extensive use of refrigerants. With this new mounting, the spectrograph is nearly ready for final adjustment at the opening of the coming academic year.

The first step in the program for the future is to redetermine wave-length standards in the extreme ultra-violet region, using the lines of hydrogen and ionized helium which can be calculated with extreme precision as the primary standards. This appears to be a necessary step on account of the considerable divergence of standards previously reported in this region.

In this program of vacuum spectroscopy there are excellent opportunities for cooperation with Professor Harrison of Massachusetts Institute of Technology, who has in operation a 21-foot vacuum spectrograph giving by far the largest dispersion and precision of any instrument operating in this spectral region. His instrument is designed to test small sections of the spectrum with high precision, whereas the 2-meter spectrograph developed with the aid of the grant from the Carnegie Institution is characterized by an unparalleled broad range covering at one exposure the entire spectral range from zero to 220 Angstroms, where it overlaps with the quartz instrument. It is planned to use the two instruments cooperatively wherever their interchange will give additional information on the problems under investigation.

Following a redetermination of standards, the program contemplates next completing work necessary to fill in the gaps of our knowledge regarding atomic spectra in the extreme ultra-violet and then passing to the very important and relatively new field of absorption and emission spectra of molecular gases in the far ultra-violet.

**Millikan, Robert A.**, California Institute of Technology, Pasadena, California. *Studies of cosmic rays.*

Immediately upon receipt of funds from Carnegie Institution of Washington, appropriated by Carnegie Corporation of New York for cosmic ray researches, the following program was organized and construction work begun at once in all its branches. Its elements are five in number, as follows:

(1) The development of a sensitive automatic recording electroscope which would be capable of use on airplanes, ships, automobiles, or trains, and thus make it possible to obtain a *permanent record*, free from all personal equation or preconception of the observer, of the variation, if any, of cosmic ray intensities with latitude, altitude, solar or sidereal time, even in localities and at altitudes accessible only by airplane.

Largely through the skill of Dr. H. Victor Neher this objective has been accomplished. An electroscope has been perfected which makes as good a record when in an automobile being driven rapidly over an ordinary road as when sitting quietly in a laboratory, and cosmic ray records are now being taken which should make it henceforth forever unnecessary to repeat the type of cosmic ray survey now being made. Future investigators or doubters will need only to come to the Norman Bridge Laboratory and read for themselves the records taken in the summer and fall of 1932. These records when completed will cover:



Sea-level records taken on shipboard from latitude 49 north to latitude 30 south; and

Airplane records taken with the cooperation of the U. S. Army and the Royal Canadian Air Force in three widely different latitudes and at a number of different altitudes up to 21,000 feet.

(2) The exploration with another new but less sensitive type of electro-scope of cosmic ray intensities at stratosphere altitudes very far above those thus far accessible. The very high regions of the atmosphere should yield new and important information about the nature of the cosmic rays. For the purposes of these tests very light self-recording electroscopes have been built and are now being carried up at Ellendale, North Dakota, and at Dallas, Texas, by very large sounding balloons obtained from Germany. These researches are being carried out by Bowen and Millikan in cooperation with the U. S. Weather Bureau and are similar to those first carried out in 1922 by these same authors under the auspices of the Carnegie Institution, but much higher altitudes should now be obtained, though at that time an altitude of nearly 10 miles was for the first time reached.

(3) The active pursuit of the measurement of the energies of the cosmic rays. These are now being made at Pasadena with the aid of a vertical Wilson cloud chamber arrangement operating in a very powerful magnetic field which is capable of directly measuring electron or proton energies up to 500,000,000 volts. With this apparatus Dr. Carl D. Anderson has already proved for the first time:

That the cosmic rays are absorbed largely by the nucleus of the atom.

That they disintegrate that nucleus, ejecting from it both positive and negative electrons with energies the great majority of which lie between 50,000,000 and 500,000,000 volts.

That they appear sometimes to eject from the nucleus positive particles which are very much more deflectable, and hence very much less massive than are protons.

That the cosmic ray is in some instances, at least, definitely a photon, since positive and negative electron tracks can be seen to originate in a lead block placed in the middle of the cloud chamber, though no track of an ionizing ray is seen to enter the lead. That this ray can not be a neutron is apparently shown by the impossibly large energy that it appears to be able to impart to an extra-nuclear electron.

(4) The active study of the relation between the local radiation, which must be measured and eliminated in all cosmic ray tests, and the uranium and thorium content of the local rocks. Certain kinds of rocks, notably some Canadian limestone and marbles, have this summer been found which are almost entirely devoid of these local radiations, while the rocks on Pikes Peak, for example, are amazingly rich in these radiations. If there is no correlation between these local rays and the uranium and thorium content of the surrounding rocks, a new and interesting property of the cosmic rays may be brought to light. If there is such correlation, new light may be thrown on the origin of the radio-active elements themselves. This study has involved the improvement of the technique for the measurement of the uranium and thorium content of rocks. This improvement has been skilfully carried out by Dr. Robley Evans at the Norman Bridge Labora-



tory, and the active use of the new technique for the above mentioned purposes is now under way.

(5) The Geiger counter as a cosmic ray detector and measurer is being actively studied. It should make possible the more certain proof that the rays do or do not originate at all in the sun. This work is being carried on by Mr. William H. Pickering.

**Shenstone, A. G.**, Princeton University, Princeton, New Jersey. *Continuation of research in spectroscopy.*

During the past year, the Carnegie Corporation of New York, by means of grants to Carnegie Institution of Washington, has provided two funds for the Department of Physics at Princeton University: (1) for the construction of a large grating room; (2) for general spectroscopic purposes.

(1) The rebuilding of a room in the laboratory to house the large concave grating was commenced in August 1931 and completed in September. The fittings were made in our own shop from our own designs and have all proved quite satisfactory. Two parts of the equipment have, however, caused us difficulty. We have found it impossible to procure a really perfect slit in this country and have ordered one from a small shop in Germany. We have also been unable to obtain steel strips for the plate holder of just the kind that we desire. No steel company seems to be able or willing to make for us perfectly uniform smooth straight strips  $\frac{1}{8}'' \times 1\frac{3}{4}'' \times 30'$  of stainless steel. We finally obtained from the research department of the U. S. Steel Corporation two strips of cold-rolled ordinary steel which must suffice, although they are far from our desire.

The work of adjusting the grating is not yet complete, but we have been able to undertake several pieces of work which did not require the utmost precision. They are listed below.

*The accurate measurement of wave-lengths in the spark spectrum of rhodium.* The work was undertaken to assist in the analysis of this very complicated spectrum on which Dr. J. J. Livingood and myself have been working for some time.

*The measurement of the wave-lengths in the spark spectrum of manganese.* The analysis of this spectrum is being undertaken by Mr. C. W. Curtis as a possible thesis for the degree of Doctor of Philosophy.

*The observation of the lines due to the isotope of hydrogen discovered by Urey and Brickwedde and Murphy* (Phys. Rev., vol. 40, 1, 1932). Dr. Urey was good enough to allow us to use some of his specially prepared hydrogen in order that confirmation of his results should be obtained with a second grating. Our observation did confirm his observation of the presence of the isotope, but indicated that it was present in considerably smaller amounts than he had estimated. He has since discovered the source of his error (Phys. Rev. vol. 40, p. 464, 1932).

(2) The grant for general spectroscopic work has been used partly for the purchase or construction of certain larger pieces of apparatus and partly for the purchase of necessary accessory equipment, such as special lenses, prisms, photographic plates, etc. It is, therefore, necessary to include all the spectroscopic work of the laboratory as being more or less indebted to the Carnegie Corporation.

The work can be roughly divided into two parts, the strictly spectroscopic problems undertaken under my direction and those problems on which spectroscopic observations are a necessary but subsidiary part of another problem.

In the first class are included the following in addition to those described in connection with the grating room: Problems on auto-ionization, problem of perturbations in series, new observations to complete the analysis of several spectra.

The phenomenon of auto-ionization was discovered in connection with anomalies in breadth and intensity in the lines of the copper arc spectrum (Cu I) and it has since been found to be fairly general in complicated spectra. It was described in a paper in the *Physical Review* (vol. 38, p. 873, 1931). During the past year, I have been endeavoring with the assistance of Mr. Curtis to obtain more quantitative results to show the details which the theory must be capable of interpreting. The lines of the copper arc spectrum have been photographed under varying conditions of pressure, current and type of discharge. The results indicate that auto-ionization is a more complicated effect than at first supposed and that, therefore, further observations will be necessary.

The spectrum of Ca I seemed promising for the elucidation of the effect, but has been disappointing. The observations which were made did, however, serve a useful purpose, since they added considerably to the knowledge of the higher series members of Ca II in which Dr. H. N. Russell is interested.

The observations of the copper spectrum also yielded a large amount of new material for the further elucidation of the spark spectrum (Cu II), which is now, as a result, very completely known.

The work on auto-ionization led us into another problem which is theoretically very similar—the explanation of the many very irregular series of terms known in various spectra. Dr. H. N. Russell and I worked on the empirical side of this problem and published our results in a paper in the *Physical Review* (vol. 39, p. 415, 1932). The problem is briefly as follows. Series of terms normally follow a Ritz formula  $T = \frac{R}{(n + \mu + \alpha T)^2}$ ,

but there are known many series which can not even approximately be fitted to such a formula. Following the indications of a letter to the editor of the *Physical Review* (vol. 38, 349, 1930) by R. M. Langer, Dr. Russell and I were successful in showing that all such series could be fitted to a formula of the type  $T = \frac{R}{\left(n + \mu + \alpha T + \frac{\beta}{T - T_0}\right)^2}$ , in which  $T_0$  is a perturbing term.

The theoretical physicists have been much interested in the success of this description of series, not only because a long-standing anomaly has been removed, but also because the explanation is one that can be deduced only from the quantum mechanics.

The design and construction of a small quartz spectrograph to be used in conjunction with Lummer plates for the measurement of hyper-fine structure in the ultra-violet was undertaken this spring. The instrument is now completed and is at present being tested.

(2) The chief problems which have involved the use of spectrographic methods and materials are as follows:

Professor R. Ladenburg, in collaboration with Dr. Boyce and Dr. Van Voorhis has completed an investigation of the absorption of oxygen for light of very short wave-lengths. For this purpose observations were made with a small fluorite spectrograph and with the large vacuum grating spectrograph built for President Compton of Massachusetts Institute of Technology from Carnegie funds while he was professor of physics in Princeton. The observations confirmed the deductions of Professor Ladenburg from entirely different experiments and added considerably to our detailed knowledge of the action of ultra-violet light on oxygen. The results are given in a letter to the editor of the *Physical Review* (vol. 40, 1018, 1932).

Mr. James F. Koehler is making a quantitative study of the quenching of the fluorescence of iodine by various admixed gases in order to lay an experimental basis for a more precise theory of the enhancement of pre-dissociation by collisions. He is using the method of photographic photometry in connection with a Steinheil spectrograph of high light power.

Dr. W. C. Michels has been engaged, for the past two years, in the study of the probability of excitation of atomic states by the impact of slow electrons. This work has been carried out by bombarding the gas atoms with a controlled electron beam and by observing the intensity of the emitted lines. The work done in this laboratory has included studies of helium and sodium, and has indicated that the probability of excitation of any state is very high for electrons with just sufficient energy to excite the state. The small spectrograph of high light power used in these experiments was built in the laboratory chiefly out of materials and optical parts purchased from the Carnegie grant.

Mr. T. C. Chow, under the direction of Professor H. D. Smyth, has been making observations of the band spectrum of  $\text{SO}_2$ , and has had considerable success in the analysis of the experimental material. Most of the work has been carried out with a Hilger quartz spectrograph purchased some time ago from a Carnegie grant.

Mr. F. C. Dahnken, under the direction of Professor Ladenburg, is engaged on the problem of the measurement of the refractive indices of metallic vapors, especially in the neighborhood of their absorption lines.

**Committee on Study of Surface Features of the Moon.** *Progress report for the period July 1931 to June 1932.* (For previous reports see Year Books Nos. 26-30.)

Physiographic studies of the surface features of the moon are dependent in part on the quality of lunar maps available. To meet this need a series of photographic maps is being prepared which represent the moon's surface as seen at the mean distance of the moon from the earth and projected on the plane of mean lunar libration. In addition to these maps, which are free from the personal factors that enter into all lunar maps heretofore prepared, oblique projections are being made, showing the moon's surface as it would appear to an observer out in space at the mean lunar distance and sighting along a direction at  $45^\circ$  to the standard line of sight. Four oblique projections from the north, east, south and west, respectively, are



being made photographically and will be of value to the student of land forms. They show in more natural form those features near the moon's limb which appear greatly foreshortened and distorted on the standard map. Photographs are also being taken with an ordinary camera of some of the features near the limb of the moon as they appear projected on the globe and viewed from directly overhead.

To be satisfactory, the transformed photographs should approach the original photographs in quality. Ordinarily this specification is not difficult to meet; but the long focal length of the 100-inch telescope (135 feet) introduces an optical path of such length (540 feet) between the original photograph and the final negative that slight disturbances in the air along the path become serious. To obtain a uniform air column, the apparatus has been housed in a special building, 140 feet long with double paper walls and roof, sheathed on the outside with corrugated sheet iron. The floor is covered with a deep layer of dry sawdust. A protected vent along the ridge of the roof allows free circulation of air in the space between the paper walls from the ground up. This arrangement favors the speedy attainment of temperature uniformity in the air within the building.

Study of the temperature distribution within the moon house has shown how seriously temperature variations in the air column along the optical path affect the quality of the image. Measurements of temperatures taken outside the building in the case of a rapid fall in temperature of  $5^{\circ}$  to  $10^{\circ}$  C., with accompanying fog, showed that the bare ground is  $2^{\circ}$  C. warmer than the air 1 inch above it; and  $3^{\circ}$  warmer than the air 6 feet above it. Inside the moon house, the temperature change lags; it may be  $5^{\circ}$  C. higher or lower, respectively, than a rapidly falling or rising outside temperature. In this case the inside air temperature responds, because of convection currents and low heat capacity of the walls and roof, more quickly than the bare ground to the outside change in temperature and soon becomes cooler or hotter than the ground. This means that the ground functions as a constant radiator or absorber of heat so long as the outside temperature is different from that inside the house. This temperature difference between bare ground and the overlying air sets up convection currents which affect the refringence of the air locally and hence the paths of the light rays. It was to supply a protecting layer of poor heat conductivity and low heat capacity that the bare ground was covered with sawdust.

Measurements within the moon house show that if the temperature difference between the ground and the air 4 inches above is  $0.1^{\circ}$  C. or less, the seeing is good at night. In the day time, the sun heats up the south walls of the building so that their temperature inside may be  $2^{\circ}$  or  $3^{\circ}$  C. hotter than the north walls on the inside. This difference in temperature of the air across the building sets up convection currents which affect the seeing. A difference of  $1^{\circ}$  C. between the ground and the air 4 inches above suffices to spoil the seeing, especially if the temperature difference be near the concave reflecting mirrors. By holding the hand temporarily in front of the concave mirror and below the path of light, the observer can destroy the sharpness of the image; but near the negative or the projection globe and away from the concave mirrors the heat from the hand has little effect



on the image. Near the image plane a slight change in direction of the light ray is not perceptible; but if the same angular deflection in the rays occurs 135 feet away it causes an appreciable shift in the image. A deviation of one second of arc at 135 feet distance means a shift of 0.2 mm. in the image and consequent blurring of the details.

A steady current of air which does not fluctuate has little effect on the image; good seeing prevails just as it may do out of doors with a steady breeze blowing. But sudden gusts of wind on striking the building set up compression waves in the air; these deflect the light rays and cause poor seeing temporarily. The use of electric fans to expedite the attainment of temperature uniformity within the moon house after nightfall is to be tested; also a more detailed study is to be made of the effectiveness of the 4 to 6 inch layer of sawdust as a heat insulating substance of low heat capacity.

In the first experimental set up of the apparatus the mounts for the negatives and the concave mirrors were made of seasoned wood bolted to heavy iron supports fastened to cement piers. Experience proved that no matter how firmly these frames were secured the optical parts shifted positions slightly and gradually with the result that during a long exposure the effect of the movements was evident in the negative. These movements ceased when the wooden supports were replaced with iron supports throughout. This experience indicates that wood, which responds to changes in humidity in the surrounding air, should not be used in instruments of the highest precision where slight changes in shape are likely to affect the results.

During the past year, the Ross zero corrector lens for the 100-inch telescope has been practically completed. It is from negatives of the moon taken with the aid of this lens that the final series of lunar maps is to be prepared.

Comparative observations on the changes produced in sunlight by reflection by lunar and terrestrial surface materials with respect both to relative intensities and to polarization for different wave-lengths are being continued. A new instrument for the measurement of the amount of polarization in a beam of light is under construction and will be used to check the results obtained with the polarization photometer eyepiece which has been employed heretofore in visual work.

W. S. ADAMS,  
J. P. BUWALDA,  
A. L. DAY,  
P. S. EPSTEIN,  
F. G. PEASE,  
EDISON PETTIT,  
H. N. RUSSELL,  
F. E. WRIGHT, *Chairman.*

## PHYSIOGRAPHY

**American Geographical Society**, New York, N. Y. (For previous reports see Year Books Nos. 29 and 30.)

### GREAT BASIN LAKE STUDIES, BY ISAAH BOWMAN

During 1931 Dr. Ernst Antevs with the support of the Carnegie Institution and in consultation with the American Geographical Society conducted studies on the bottom deposits of certain lakes of the Great Basin and collected tree-ring records from adjacent slopes. The sedimentary material was entrusted to Dr. Twenhofel of the University of Wisconsin for detailed analysis. The tree-ring records were submitted to Dr. Douglass of Tucson. The careful study of the reports from these two sources will be the next step. To provide additional material, the writer visited supplementary and more remote localities in the Great Basin during 1932, following the general plan adopted in 1931, with the result that a number of bottom deposits and tree sections were procured. It is hoped that some of them will have critical value. A detailed study was also made of the special case of Granite Lake, near Spokane, where the rise of the water in years past drowned the trees whose trunks are now visible in the lake and about its shores. It will be more appropriate to discuss the scientific aspects of the problem at a later time, when the two seasons' field work has been thoroughly analyzed.

### COMPLETION OF STUDY OF DELTA OF COLORADO RIVER, BY GODFREY SYKES

Progress made with the investigation during the past year has centered about certain physiographic and hydrologic problems presented by recent developments in the active portion of the delta. Rapid change has been brought about by a quick transition from a protracted period of extreme low-water stages, to a summer flood season substantially above the average, and extensive field studies have been carried out in the areas most affected.

The fluctuation in volume of river flow may be appreciated by a comparison of the discharge figures for mid-September 1931 (when it had dwindled to less than 200 second-feet, which represents practically zero for a great river such as the Colorado) with those for June 1932 (when it exceeded 90,000 second-feet). A ratio of 1 to 450 was found to subsist between these two successive high-water periods.

It may be well to review briefly some of the conditions and events which preceded the great cycle of change through which the lower Colorado and its delta have been passing during the last twenty-five years, a cycle which may now be considered to be approaching its final phase.

### RECENT PHYSIOGRAPHIC HISTORY OF THE DELTA

Exceptionally heavy rains which occurred throughout the Gila basin during the winter of 1890-91, brought a sudden rush of floodwater into the Colorado, which rose at the point of juncture to the unprecedented gage height of 33.5 feet. Passing down into the delta, the combined flow overtopped the river banks for a distance of many miles, opened breaches

in the western one at several vulnerable points, and during the ensuing weeks passed in great volume through the Alamo, Paredones and other usually dry watercourses, down the western slopes of the delta. The waters then divided, one portion flowing over the rim of the depressed valley to the northwest and into the Salton basin; another, entering the ephemeral lagoon area known as Volcano Lake and impinging against the bajadas of the Cerro Prieto and the Cocopahs, was diverted toward the south, through the channel of the Hardy, to a reunion at the head of the estuary with such of the flood waters as had passed directly down the main channel of the Colorado and so, eventually, to the sea.

Although this great flood was not followed by another of equal or even approximate magnitude for a number of years, and the breaches made in the river banks automatically sealed themselves after a few seasons, it was in a sense the prelude to impending changes, inasmuch as it indicated the increasing instability of the river channel and, by the great circuit made by the water which escaped toward the southwest, defined an area of some 1000 square miles over which the river would wander should it again break away as high up on the flanks of the delta cone. Since this delimiting flood, practically every square mile within the area has in fact been reached by running water from the Colorado.

A few minor excursions of water toward the west occurred during the next fifteen years, showing its general tendency to leave the channel in that direction and, also within this period, the great although largely accidental outbreak took place through an excavated opening in the river bank, which gave birth to the Salton Sea, necessitating vast and expensive engineering operations to effect a closure.

The river was returned to its old channel in February 1907, but by the summer of 1908 it had definitely broken away toward the west, passing first through the Paredones channel and afterward through the Rio Abejas, along a roughly parallel course, although several miles farther to the south. Through either of these channels the water reached the Volcano Lake region and the Hardy. A portion of the flow still passed down the old Colorado channel until 1909, but thereafter entirely ceased.

The Rio Abejas continued to carry practically the entire river, although with sundry minor breaks toward the west and southwest, until 1923. The channel was then dammed and a diversion cut was excavated from a point in its southern bank for a distance of several miles south. The river occupied this channel until 1927, but has since selected another route farther to the east, through which it is still passing, and by means of which it is again approaching its former course near to the eastern margin of the delta. It has thus described, during the past 25 years, an arc of about 90°, with a radial sweep of some 25 to 30 miles.

#### PRESENT CONDITIONS, AND THE FEATURES NOW UNDER INVESTIGATION

The Colorado water carries in suspension an average annual load of solid matter which has been estimated as being substantially in excess of 70,000,000 cubic yards. Under present conditions, practically all of such matter reaching the lower river is retained and distributed above tide-water. The manner and extent of this distribution has formed during



recent years the central theme in the investigation of the physiographic conditions in the delta of rapid channel changes, and several areas of deposition have been observed through the successive phases of invasion, development and final abandonment by the depositing current.

An equally important though much less easily measurable portion of the detrital material carried by a heavily burdened river such as the Colorado is the rolling, or saltatory, load of particles too large and heavy to be held in actual suspension in the water, but which the current is still competent to move forward.

A sudden change, during the past winter, in the appearance and method of development of the extensive fan, which has been slowly forming at the lower end of the present open channel since 1930, has been attributed to the arrival within the area of a great volume of material of this character, and it has formed the subject of much recent field work.

Storms in central Arizona caused a discharge of over 50,000 second-feet from Bill Williams Fork early in February. This intermittent stream drains an area in which sands and gravels predominate, and the coarse heavy material issuing from its mouth in times of flood has frequently formed large obstructive bars in the Colorado channel at the point of debouchure. The almost simultaneous arrival of flood-waters from the Little Colorado and Virgin appear in this instance to have carried the mass down stream as a saltatory load, practically in a body, until the lessening currents in the area of dispersal in the delta caused deposition to take place very rapidly.

The flood was a brief one, decreasing in volume to about one-third in less than a week after the passing of its crest. As the flow lessened, it was realized that an amount of detrital material, entirely out of proportion to the volume of the flood, had been brought into and deposited within the area under observation. The newly laid top-set beds have not yet been thoroughly examined or their extent fully determined, as the long-sustained summer flood condition of the river has so far made access to the region difficult. However, the general character and appearance of the deposit is suggestive of a common cause of origin for this and for certain similar areas not hitherto fully understood and which have been observed in other parts of the delta.

The width of the barrier zone is about 7 miles. With the addition of the new beds, it now appears to form an almost insuperable obstacle to any further direct advance of the Vacanora channel toward the south. Unless radical changes take place within the next season or two and the water passes clear of the entire region, a local diversion will undoubtedly take place before conditions there become stabilized.

Most of the small streams issuing from the lower margin of the dispersal area unite within a few miles to form a well-defined channel which now joins the Hardy at a point some 10 miles northwest of the situation of the junction of the two streams in 1890, when it was located and mapped by the original expedition made between Yuma and the Gulf in connection with this investigation.

This distance, and that which still separates the Vacanora channel from the old course of the Colorado along the foot of the Sonoran mesa, indi-



cates with fair accuracy the zone through which the river must move before its present cycle of unrest is completed.

A straightened and cleared channel, following the general alignment of the old navigable route, would give the most direct route between the mouth of the Gila and the sea, and practically the only one capable of safely passing the occasional floods which will reach the lower river even after the completion of the Black Canyon and Los Angeles Aqueduct impounding dams.

The work in progress as this report closes is the continuing examination of the newly deposited beds; both topographically and by means of silt examinations and comparisons, the further investigation and preliminary mapping of the gathering channels below the dispersal area to their junction with the Hardy, and the periodical inspections of the shores and tidal channels of the estuary.

RECONNAISSANCE SURVEY OF FORMER SHORELINES ALONG THE  
ATLANTIC AND GULF COASTS, BY DOUGLAS JOHNSON

In the spring and summer of 1931, the writer made a reconnaissance survey of coastal terraces and other possible evidences of former marine levels from Rhode Island down the Atlantic Coast to Florida, thence along the Gulf Coast as far as Corpus Christi, Texas. The work was made possible by an initial gift of \$500 contributed by Count David A. Costantini of Paris through the American Geographical Society, supplemented by like sums from the Carnegie Institution of Washington and Columbia University and it was conducted under the joint auspices of the three institutions named. The American Geographical Society arranged for important surveys in Connecticut by members of the Society's staff and otherwise aided the enterprise; valuable help was contributed by the United States Geological Survey, The Pennsylvania Geological Survey, and other Federal and State bureaus, as well as by many individuals.

The object of the investigation was not so much to establish definite conclusions regarding the vexed problem of correlating ancient marine levels in any specific area, as it was to determine the causes of existing wide divergences of view on this subject and to develop if possible improved methods of investigation and correlation which should lead to more harmonious results in future studies. To this end three lines of approach were pursued:

- (1) Where different investigators have diversely interpreted the same terraces or other coastal forms, the areas were examined in the light of the conflicting theories, so far as possible in company with those who have entertained the various views. Thanks to the cordial cooperation of all concerned, these field discussions were most helpful and served to focus attention on the particular evidence or arguments which led to divergent conclusions. From the discussions came a number of suggestions which should be helpful in any future studies of this type.

- (2) Where differences of opinion have existed with respect to facts of critical importance, detailed surveys of selected areas were undertaken. Such surveys were prosecuted in the Connecticut Valley to determine whether certain terraces of that region were horizontal or inclined; and

along parts of the lower Susquehanna to determine whether the successive terraces of that area intersected the present stream course or continued more or less nearly parallel with it. In both cases the work not only accomplished the specific end of settling disputed questions of fact, but in addition contributed materially to our knowledge of possible variations in terrace form and structure, and of the extent to which terraces in stream valleys may be expected to indicate changes in sea-level. The chief value, however, of this part of the work was the light it shed upon the causes of divergent conclusions and the suggestions it afforded regarding possible improved technique in terrace studies.

(3) Other areas were selected for study by means of a large series of closely spaced projected profiles, with a view to restoring the dissected upland surface in a manner permitting detailed analysis of terrace forms nearly destroyed by erosion. These areas include a small section of Connecticut and extended portions of the Maryland-Virginia Piedmont. The preparation of the profiles has been a laborious task extending over a long period; but the work was completed in the summer of 1932, and the materials are now available for this part of the study. It is hoped that the analysis of the profiles will give results of practical value to other students of similar forms.

A brief report on the results thus far obtained was published in the *Geographical Review* for April 1932. The work was more fully discussed at the Paris meeting of the International Geographical Congress in the fall of 1931, in a report which will appear in the near future in the *Comptes Rendus* of the Congress. Both reports are chiefly concerned with analyzing causes of the existing wide differences of opinion among students of marine-level correlation, a number of these causes being catalogued and commented upon, and with the presentation of a proposed systematic method of marine-level study, which it is believed will result in an improved technique in investigations of this type. Since this material is available to the reader in the citations given above, it will not be repeated here.

A detailed report on the Susquehanna region, accompanied by excellent new maps of the terraces, has been prepared by Mr. J. H. Mackin who was in charge of the surveys there, and is ready for publication. Other parts of the work are well advanced and will be published in due course. Among these is a detailed discussion of the origin and evolution of the Pensacola terrace of Florida as related to the antiquity of the human remains discovered at Melbourne and Vero.

STUDY OF DROWNED FORESTS IN NEW ENGLAND AND NOVA SCOTIA,  
BY CHARLES J. LYON AND JAMES W. GOLDTHWAIT

The object of the study was to discover whether it is possible, through measurements of rings of growth of trees in these drowned forests, to trace the chronology of the submergence. With good data, in sufficient quantity, we might hope to determine the rate of submergence, its date (if very recent) and even the character of submergence—whether due to rise of sea or lowering of land, and whether regional or local.

The best five of some fifteen forests visited were selected for detailed study: Rye, New Hampshire; Scarboro, Maine; Provincetown, Massachu-

setts; Fort Lawrence and Grand Pre, Nova Scotia. Each forest was mapped to show exact positions and ground altitudes of individual stumps and logs, and sample sections of about 80 of the best trees were cut for study. From 10 to 25 samples were secured at each locality, most of these trees being between 90 and 200 years in age. Distances between them, both vertically and horizontally, were moderate and seemed to justify hope that they could be cross-dated.

After the sections had been slowly dried in the laboratory, accurate measurements of thicknesses of rings were made, with binocular, on four radii wherever possible, and average values for yearly growth were plotted, ring by ring, in graphs. The resulting curves for the 80 trees show good character, with marked oscillations in growth suggestive of climatic influence. Taken singly, the graphs look very promising.

Although to casual observation most of the trees seemed to be white pine, less than one-third of those sampled actually proved to be. Identification by the U. S. Forest Products Laboratory, at Madison, Wisconsin, disclosed at least 9 species in the collection and as many as 6 species from a single locality.

Much the best record is that from the classic drowned forest at Fort Lawrence, where 225 stumps and fallen logs were mapped in a distance of 600 feet and through a vertical range of about 10 feet. Of the 22 samples gathered from the best trees in this forest, 10 are balsam fir (all at the lower zone of the forest) and 6 are hemlock, with a few beech, pine, maple and spruce. There would seem to be expectation for cross-dating the records of 8 firs whose ages are from 70 to over 100 years, on ground that slopes not more than 1.5 feet, or for cross-dating the records of 6 hemlocks aged from 100 to 175 years, on ground that ranges vertically only 2.5 feet.

In all cases, nevertheless, attempts to match the curves are unsuccessful. Correspondences in fluctuation of the curves are short, fragmentary and inconsistent, both with one another and with the theory of progressive drowning. We find not a single satisfactory case of approximate parallelism between curves through a period of 30 or 40 years.

It is probably too much to expect trees of different species, even growing in close proximity, to display parallel fluctuations in growth, season by season; and part of our difficulty doubtless lies in the unexpected diversity of types. But the failure to match graphs of similar individuals in the balsam fir group and again in the hemlock group at Fort Lawrence, where all conditions appear favorable, leads us to suspect that individual trees may have been more strongly influenced by place effects on nutrition than by climatic factors. There is also the possibility that the rise of sea-level was so slow—especially if due to melt-water reentering the sea in late glacial time—that the time interval between deaths of trees at successive levels was greater than that recorded by the trees themselves.



## PHYSIOLOGY

**Hartman, Frank A.**, University of Buffalo, Buffalo, New York. *Experimental studies indicating the function of cortin.*

Funds for these studies were appropriated by the Carnegie Corporation of New York to Carnegie Institution of Washington.

Evidence at present available indicates that cortin, the vital hormone of the adrenal cortex, is a general tissue hormone. However, if for no other reason than the importance of the tissues involved, cortin plays a paramount rôle in the function of the nervous and muscular systems. This substance is necessary for the maintenance of normal metabolism, growth, resistance to toxins and kidney function. We have already shown that the lower nerve centers need it for their activity. Clinical studies and experiments on normal human individuals indicate that it is also necessary for the higher nervous centers. Recently Anderson, Liddell and Hartman have been able to show by means of experiments on animals that it has an effect on centers in the brain. Neurotic sheep were much improved and tended to behave like normal individuals after the injection of cortin. These results in animals place beyond a doubt the influence of cortin on the higher centers.

The following papers, which will soon be published, summarize the experimental work on animals and clinical experience with cortin to date:

*Studies Indicating the Function of Cortin*, by Frank A. Hartman, K. A. Brownell and J. E. Lockwood.

*Further Experience with Cortin Therapy*, by Frank A. Hartman, C. W. Greene, B. D. Bowen and G. W. Thorn.

A preliminary paper by Dr. W. J. Atwell of the Anatomy Department of the University of Buffalo, entitled *Effects of Administration of Cortin to the Hypophysectomized Rat*, has been published in the Proceedings of the Society for Experimental Biology and Medicine, June 1932.

We have also carried on some experiments in collaboration with Dr. H. S. Liddell and Dr. O. D. Anderson, of Cornell University, on the effect of cortin in conditioned reflexes. The results with neurasthenic goats have been very striking. This work, however, will not be published for some time as additional experiments must be carried out. We have also aided Dr. P. C. Baird at the Massachusetts General Hospital with some work that he is doing on hypophysectomized rats.

**Phelps, Earle B.**, College of Physicians and Surgeons, New York, N. Y. *Effect of solar radiation upon the atmosphere in relation to health.*

The following report is submitted as a result of studies undertaken by means of a grant from the Carnegie Corporation of New York to Carnegie Institution of Washington.

Our major work has been the setting up of apparatus for the study of the atmosphere. Ample quarters have been provided on the 17th floor of the Medical School, and apparatus for the continuous sampling and testing of the air from a point 10 feet above the roof has been installed. We are



making routine observations upon positive and negative conductivity and positive and negative ion counts. Work is in progress upon a recording apparatus for these four determinations and also upon a means of measuring the horizontal air transparency as a measure of dust and fog.

A portable apparatus was constructed and set up at Harwich, on Cape Cod, where a very satisfactory set of readings of the ion count, both signs, was obtained before, during and after the eclipse, and on some control days later.

The biological attack on the problem of health as affected by air conditions is being carried out by controlled experiments which simulate the processes which may occur under ordinary living conditions or in nature.

For this purpose we have used the hemolytic streptococcus. This is a virulent organism in northern climates and apparently innocuous in warm southern latitudes. The cause of this difference may lie in the organism or in the host. There is evidence in the literature for a change in both.

In our laboratory experiments, an attempt has been made to find whether any change is produced in the streptococcus (as evidenced by change in the appearance of colony form) by exposing it to radiation or radiated air. The procedure involved spraying the organisms into a glass box which had been previously radiated or in which the air had been ionized, and allowing the organisms to settle on agar plates or else in allowing them to settle while exposed to radiation. The results obtained in either case contain a suggestion that there is a change toward non-virulence but, because of several factors which could not be properly controlled, further work has been postponed for the time being in favor of a more promising line of attack.

It was noted that the radiation produced a considerable amount of killing which, although not a new point, is of interest in our problem.

Experiments are now being performed in which streptococcus organisms are placed on the surface of agar and exposed to a stream of sunned air, but not to the sun directly. This, in a way, approximates the effect of sunned air on an organism deposited on a body surface. The results which have been obtained are most suggestive but not yet conclusive, and further work is in progress.

Experiments are being carried out also to study the effect of ozone and hydrogen peroxide on the virulence of the streptococcus. It has been reported in the literature that the virulent form of streptococcus is very sensitive to peroxide and that dissociation or transformation of a culture to a non-virulent type is favored by this reagent. Furthermore, there are published statements that considerable quantities of peroxide are formed by the action of sun on moist air. Our results thus far indicate a fair degree of tolerance of our particular organism for peroxide. Experiments on the production of peroxide by New York sunlight have thus far given entirely negative results.

Another phase of the work under way is the effect of sunned air on animals. White mice are being used. Lots of these animals are being kept in two screened compartments under identical conditions, except that the air in one compartment is freed of ions as it enters. This experiment simulates in a way the conditions in New York City schools where the difference

between mechanical and window ventilation appeared to be due to the removal of something, possibly ions, from the air. The experiments are in progress. After a period of time the animals in the two compartments will be tested as to the germicidal properties of their blood (there is good reason to believe that there may be a difference) and also for their resistance to streptococcus infection.

Our large solaria proved too hot for this animal work during the summer, but with the approach of cooler weather animal experiments on a larger scale are planned. The animals in each case will be exposed to sunned air with and without ultra-violet and their resistance to decrease will be noted.

Briefly, in approaching our problem along a rather broad front, we have exposed a few promising lines which we propose to investigate in detail and at length.

The personnel engaged upon this work has been Professor E. B. Phelps, and Dr. M. L. Isaacs practically full time for two-thirds of the year; Mr. Murry Brimberg, half time; Miss Joanna Jennings, full time; Mr. Iza Zeiber, full time. Of these the time of Miss Jennings has been charged to Carnegie funds, the greater part of which, however, have gone into construction of the solaria and measuring apparatus, the cost of animals and supplies, etc.

**Russell, G. Oscar**, Ohio State University, Columbus, Ohio. *Physiological cause of voice quality differences*. (For previous report see Year Books Nos. 28-30.)

Conditions during the past year have been about as unfavorable as one could ever expect to encounter. Previous reports have indicated that support for the present investigation has been forthcoming not only from the grant authorized by the Carnegie Corporation of New York through the Carnegie Institution of Washington, but also in no small measure from the funds, apparatus, facilities for work, and personnel cooperation rendered by many private corporations, such as the General Electric Co., the Eastman Kodak Co., the Aeolian Co., the Electro-Surgical Instrument Co., and the private individuals represented in the membership of the American Academy of Teachers of Singing, as well as large numbers of prominent operatic, oratorial and concert stars from both the United States and abroad. The financial stringency affected rather violently not only the private corporations but also the whole field of artistic endeavor. It was practically impossible to get even a semblance of the support heretofore rendered.

In the course of last summer while teaching at the University of Michigan, Dr. Russell succeeded finally in synchronizing the actual sound produced with the moving pictures of the vocal cords in action during the production of varying voice qualities. (The first actual photographic motion picture part of this phase of the investigation was reported on page 464 of Carnegie Year Book No. 30, and was conducted in collaboration with Clifton J. Tuttle of Eastman Research Laboratories.) The original synchronized sound record was made by the Western Electric photographic process and required apparatus for projection and study purposes which was so expensive that it would have used the full amount of the grant originally allotted us. Since in these times of stringency it was not possible

to get either the Western Electric or Photophone Corporation to loan us such apparatus and the \$10,000 necessary to purchase the same was not forthcoming from any other source, it became necessary to develop apparatus using 16-mm. film and retake this series of photographs. This rather painstaking task was successfully accomplished in the course of this last year and is probably our major contribution since the last report.

This motion-picture study of vocal-cord action shows conclusively that the cause of most bad voice qualities may be sought in a function of the interior vocal cord action and of the superior laryngeal and pharyngeal function rather than the heretofore assumed failure to utilize nasal and head cavity resonance. Furthermore, by means of the 16-mm. motion picture and sound accompaniment, the clearly observable and easily demonstrable evidence can now be presented first hand before all who care to study the same.

This evidence was presented in the course of the year in a series of papers: one on *Bad Voice Qualities Among the Deaf and Hard of Hearing*, before the convention of American Instructors of the Deaf, meeting in Winnipeg, Canada, June 1931; a series on the general subject of *Musical and Voice Acoustics* along with Professor Redfield, John Philip Sousa and others before the National Orchestra Summer School at Interlaken, Michigan, July 25 to August 15; another on *Vocal Cord Moving Pictures of Operatic Stars*, before the Chicago Council of Teachers of Singing, meeting in Chicago, October 20, 1931; one on *The Function of the Interior Larynx*, before the Cincinnati Oto-Laryngologic Society, meeting in Cincinnati, November 17, 1931; one on *The Laryngological Cause of Certain Types of Dysphonia*, before the American Society for the Study of the Disorders of Speech, January 2, 1932; one before representatives of the Carnegie Institution of Washington, March 24, 1932; another on *New Light on Interior Laryngeal Function Through Synchronized Sound Movies Thereof*, before the Academy of Medicine in Cincinnati, March 28, 1932, who also invited as their guests, all the teachers of voice, speech, and of the deaf and hard of hearing in the city, who attended in large numbers; and a series of these studies was also incorporated in a general résumé of the year's activities given before the American Academy of Teachers of Singing, meeting in New York on March 23, 1932.

The principal contribution made in this last study lies in the fact that it was carried out by means of the laryngoperiskop which, passing as it does in and around the tongue, gives a motion picture of the interior larynx in function without any impediment of the extrinsic muscles or of the pharyngeal and buccal muscles, such as those represented in the tongue or genio-glossus. Without repeating, it may be said that in general they confirm the observed results indicated on pages 465-466 of Year Book No. 30.

At least six publications have recently appeared which bear directly on the subject under investigation. One a dissertation *Untersuchungen über die menschliche Singstimme—Ein Beitrag zur mathematischen Statistik*, Paul Schläper, Göttingen 1927; another, *Breathing Movements in Singing*, by R. H. Stetson, The Archives Néerlandaises de Phonétique Expérimentale, Tome VI (1931). *The Vibrato*, an elaborate series of studies on this phase of voice quality by 12 authors, appeared under the general direction of



Dean Carl E. Seashore, University Iowa Studies No. 225, April 1932. Three others deal more specifically with the immediate question of voice quality physiological differences.

One study, *The Relation of the Paranasal Sinuses to the Singing Voice*, is announced by Francis Wheeler, vol. LXXII, No. 1988, Science. The author reaches conclusions not sustained by our study of prominent singing voices, viz:

"First, the range of the voice seems to be governed by the length of the resonating space in the frontal sinuses. Practically all the cases examined have shown a direct relationship between the range of the voice and size and shape of the frontal sinuses, sopranos having long, narrow, frontal sinuses, mezzo-soprano shorter and broader ones, and altos very short and almost round ones. The cases examined have run unusually true to type.

"Second, the size or weight of the voice seems to be governed by the size of the antri, clear light sopranos having smaller antri than those having larger, heavier voices.

"Third, the naturally beautiful voices seem to have arches, palatal and pharyngeal, that are symmetrical in their make-up, well-arched cases having more beauty in their voices than those having flat arches.

"A thorough investigation is under way by the writer, and plans are now being formed to radiograph a large number of distinguished singers' heads."

Another article, *Chest Resonance*, was published by C. M. Wise (Quar. Jour. Speech, vol. XVIII, 446, No. 3, June 1932), in which the author announces results of an experiment conducted during the summer of 1931 by himself, Professor Robert West of the University of Wisconsin and Mr. Barrett Stout of Kirksville State Teachers College. They used a tuning fork as a sound stimulating source, and a stethoscope later supplemented by a noise meter in order to trace the conduction of sound from the stimulating source through various surfaces. Among other interesting observations, they note that variation in the tenseness of muscles affects the sound transmission which becomes increasingly greater with increasing muscular tension. They likewise conclude that "vibrations reach the chest from above by bone, tendon, muscle adipose tissue and air"; and that this sound may be radiated from both the posterior and anterior thoracic wall after the order of a sounding board, though it would appear that the limited apparatus at their disposal did not indicate any great volume could be thus radiated.

Another interesting study has been announced by Charles Frederick Lindsley, a former Ohio State University student, whose dissertation is released by the University of Southern California under the direction of Professor Milton Metfessel. He used an electrical stethoscope with sound filters, an oscillograph, a phonoprojectoscope, and a kymograph. He summarizes his findings as follows:

1. The greatest amount of voice vibration is recorded at the larynx. Laryngeal vibration varies according to the character of the vowel.

2. Vocal tone produces vibrations throughout a wide area of the chest, throat, face and head. In so far as the bones of the face act as sounding boards, voice quality depends on the structure and functioning of the vocal cords.



3. In general the most active resonators according to the amount of vibrations produced in the walls thereof are the pharynx, the lower jaw, the chest, the top of the head, the nasal framework, the left and right sinuses, and the frontal sinus.

It is of interest to note that his results confirm those announced by our investigation of last year and contradict those of Francis Wheeler, above mentioned; since the right and left sinuses and the frontal sinus show the weakest involvement of the group named.

## PSYCHOLOGY

**Ruger, Henry A.**, Teachers College, Columbia University, New York, *Studies on the theory of surfaces*. (For previous reports see Year Books Nos. 27, 29 and 30.)

The following report is submitted as the result of continued studies undertaken with appropriation of funds by Carnegie Corporation of New York to the Carnegie Institution of Washington, on Generalized Frequency Surface Research. This work has been carried on in direct cooperation with Professor Karl Pearson, of University College, London.

The Frequency Surface Research is to include two series of studies. The first of these is to be mainly empirical while the second is planned to be more theoretical in character.

The empirical series is concerned with the further reduction of data on about 7000 males measured by Sir Francis Galton in respect to a number of anatomical, motor and perceptual traits.

A first reduction of the data was reported in a paper published in the *Annals of Eugenics* (vol. II, pp. 76-110, April 1927). This paper gave in tabular and graphic form the variation of means of the various traits with respect to age. The age range was from 6 to 81 years. Smooth curves or trend lines showed characteristic differences between the traits in respect to the form and rate of the rise to a maximum efficiency, and the more or less rapid fall therefrom with increasing age. The anatomical characters and the perceptual judgment traits were relatively slightly and tardily influenced by age, whereas the motor responses and sensory acuities were sharply and early affected. In general, all trend or regression lines plotted against age are curvilinear and the corresponding correlations with age are non-linear and require a suitable coefficient. Correlation-ratios were employed in this connection. These showed varying but wide divergence from the corresponding product-moment correlation coefficients, which presupposes linearity. Similar age curves for absolute and relative variabilities were given. The location of the age (called the "prime") corresponding to maximum efficiency for the various curves was an interesting feature, as were the results for swiftness of blow, the latter because of its novelty and its relation to athletic sports.

As was stated above, the empirical studies involve further statistical reduction of the Galton data just referred to. The first paper, now relatively complete, presents the correlations and regressions for age-corrected or standard scores. The standard age, chosen somewhat arbitrarily, was 40 years. For example, from the height of a 13-year boy was subtracted the smoothed mean value for all 13-year-old boys. This difference or residual was multiplied by the ratio of the smoothed variability of 40-year-old men to that of 13-year-old boys and the standardized residual resulting was added to the smoothed mean height of 40-year-old men. Twenty-eight correlation tables of these standardized age-corrected scores for the total population of about 7000 males are included in this paper. The trend lines are represented for each table and for both traits in each table. Both the array means and their smoothed values are shown for each of the 56 regressions. The standard deviations of each array are plotted with respect to the array means. Thus both the trends and variabilities about them are shown in detail as well as in smoothed form. Correlation-ratios as well as correlation coefficients have been computed for each of these tables. The trend or regression lines of these age-corrected scores, as fitted by the method of least squares, were straight lines or parabolas of low degree. The publication in *Annals of Eugenics* (vol. III) of a study of Growth Curves in Women by Ethel Elderton and Margret Moul makes possible a comparison of the age-corrected regression for males with those for females.

The second empirical paper referred to is concerned with the relation of the correlations and regressions for the various special age groups to the corresponding values for the total population in the case of these age-standardized scores. Do the former vary at random or systematically and how much do they differ from the value for the total age-corrected population? How representative is the partial correlation coefficient or correlation ratio obtained from the whole population for the separate groups of which it is composed? Corresponding to the 28 age groups for each 28 pairs of traits, 784 correlation tables, each for an average population of 250, have been set up and the corresponding correlation coefficients and correlation-ratios have been computed. These are presented in tabular and graphical form and their relations to the corresponding constants for the whole population is exhibited. The material for this paper is also relatively complete.

The third paper deals with variations of moments for age-corrected partial populations and their relations to values found in the total population studied. It is similar in scope and character to the second paper, but refers particularly to the variations of higher moments and especially of higher product-moments. Considerable statistical reduction is yet to be done.

## SEISMOLOGY

### REPORT OF THE ADVISORY COMMITTEE

(FOR PREVIOUS REPORTS, SEE YEAR BOOKS NOS. 20-30)

#### THE SAN ANDREAS RIFT IN THE DESERT REGION OF SOUTHEASTERN CALIFORNIA<sup>1</sup>

In the Carnegie Institution Year Book No. 25 for the year 1925-26 was printed a summary of the progress of the work of Dr. L. F. Noble to that date in studying and mapping some of the active faults in the desert region of southeastern California. The work included two projects. The first was a study of the San Andreas fault from the region about Tejon Pass southward along the border of Mohave Desert and through Cajon and San Geronimo passes into the Salton Basin. The second project was a study of the faults and areal geology of the Death Valley region. Field work on the first project was completed in January 1932. A brief summary of some of the results of that work is presented herewith. Work on the Death Valley project is still in progress.

The study of the San Andreas fault covers in detail a sector of the fault 80 miles in length, extending from Elizabeth Lake on the border of Mohave Desert southeastward to the mouth of Waterman Canyon on the edge of San Bernardino Valley. An area averaging about 10 miles wide along the fault was mapped in detail on a scale of 1:62,500. Two of the new topographic sheets of the Geological Survey, the Little Rock and Pearland quadrangles, were mapped on a scale of 1:24,000. These two topographic maps, which are constructed with five-foot contours, constitute the most satisfactory and graphic representations of any part of the San Andreas fault. During the last year of the work, the author was assisted by C. L. Gazin. The mapping of all the San Andreas fault zone from Elizabeth Lake to Little Rock Creek was done by Mr. Gazin as well as the mapping of a part of the region about Cajon Pass.

Southeastward from Waterman Canyon and on into the Salton Basin the fault was covered by reconnaissance. This area had already been studied by Dr. J. P. Buwalda in an investigation of routes for the Colorado River Aqueduct of the Metropolitan Water District, and Doctor Buwalda's material was generously put at the disposal of the author.

The study of the San Andreas fault was materially aided by a magnificent set of aerial photographs extending from Palmdale to the Mexican boundary. Without these photographs, the tracing of some of the recently active features of the fault would have been impossible. The photographs were made under the direction of Doctor Ransome for the Metropolitan Water District and a set was given to the Geological Survey and made available to the author.

The results of the study of the San Andreas fault will be submitted in detail to the Geological Survey at a later date. The author expects to complete this report during the coming winter.

The most difficult problem in the study of the San Andreas fault was the

<sup>1</sup> By Dr. L. F. Noble. Printed by permission of the Director of the U. S. Geological Survey.



determination of the age and stratigraphic sequence of the rocks exposed along it. The rock masses at most places along the fault form long slivers, isolated one from another by faulting, so that all contacts are faults. The Tertiary and Quaternary beds exhibit rapid changes in lithology in short distances. At no place along the 80 miles of the fault studied in detail are the Tertiary beds similar in lithology on opposite sides of the fault. What few age determinations have been made are chiefly the result of a careful search for fossils by Mr. Gazin. The most satisfactory results were obtained in the area about Cajon Pass. Fossils were obtained there in three sets of Tertiary beds—one set, a marine formation, yielded remains of a whale associated with turrיתellas and clams of Vaqueros age. Another series of beds—a land-laid formation, unconformably overlying the Vaqueros—yielded vertebrate remains whose age is approximately that of the upper Miocene Barstow formation. A still younger land-laid formation yielded similar upper Miocene vertebrate remains, although the formation, curiously, is separated from the one just described by an angular unconformity. The fossils were found only in the basal beds, which seemingly pass upward without profound stratigraphic break into Pliocene and lower Quaternary deposits. This angular unconformity between formations carrying fossils of approximately similar age affords striking testimony of the vigor of tectonic activity near the San Andreas fault even in Miocene time. Unfortunately the Tertiary beds in Cajon Pass can not be traced with certainty northwestward into Tertiary beds exposed along the rift northwest of Rock Creek. Near Palmdale, Mr. Gazin found, in poorly consolidated beds, vertebrate material which appears to be roughly approximate in age to the Quaternary Rancho La Brea fauna. Near Rock Creek, abundant fossils of Martinez age determine the age of a thick series of sandstones. Overlying this series is a set of beds lithologically similar to the older upper Miocene beds of Cajon Pass containing similar vertebrate remains.

The age of the pre-Tertiary crystalline rock masses along the San Andreas fault is even more difficult to determine than that of the Tertiary sedimentary rocks. In the face of Ord Mountain east of Hesperia, the author found crinoid stems in limestone beds injected by granite. The limestone is therefore of Paleozoic age and the granite probably Mesozoic. Similar limestones are exposed at many places along the rift. The age of the Pelona schist, exposed at so many places along the San Andreas fault, is unknown. In the opinion of the author the Pelona may be the approximate equivalent of the Rand schist of the Randsburg district with which it is lithologically similar. The Rand schist is believed to be of pre-Cambrian age. The age of the complex assemblage of gneisses and granites which forms the core of the San Gabriel and San Bernardino ranges is likewise unknown. Some of the gneisses are believed to be pre-Cambrian and most of the massive granites Mesozoic. Some limestones associated with gneisses may be pre-Cambrian.

Perhaps the most interesting problem in the study of the San Andreas fault is the nature of the major movements that have taken place along it. Many geologists believe that the movements have been mainly horizontal and that they have taken place upon a huge scale. For example, an inspection of a map of southern California suggests that the San Bernardino Range north of the fault has been shifted many miles southeastward with reference to the San Gabriel Range south of the fault. The suggestion



is strengthened by the fact that the pre-Tertiary rock cores of the two mountain masses are roughly similar. The author has studied carefully the rock masses exposed along the rift with this suggestion in mind. No definite stratigraphic evidence of horizontal movement on such a scale was obtained. The evidences of horizontal movement, indeed, are contradictory. West of Palmdale one pre-Tertiary formation, the Pelona schist, lies on opposite sides of the fault in such a way as to suggest a horizontal movement in a direction exactly opposite to that necessary to pull the San Bernardino and San Gabriel masses apart. On the other hand, as stated in the author's former report in this publication, two associated sets of Tertiary beds north of the fault in Cajon Pass may be matched lithologically by two sets of similar Tertiary beds exposed on the opposite side of the fault at Rock Creek, 24 miles distant. It is of course possible that the contradictory evidence west of Palmdale is apparent only, for the opposed wedge of Pelona schist north of the fault forms a long narrow ridge (Portal Ridge) that lies entirely within the fault zone and may have moved independently of the rock masses bordering the fault zone.

The topographic evidence of horizontal shift is more definite and convincing than the stratigraphic evidence, but is also contradictory. In the area about the lower canyon of Cajon Creek there is abundant evidence of horizontal movement in late Quaternary time. Stream courses that cross the fault have been shifted several hundred feet, and the direction of offset is southeast on the north side of the fault. Earlier Quaternary offsets in the same direction amounting to a mile or more have apparently taken place where the fault crosses Cajon Creek and where it crosses several creeks between Cajon and Cable canyons. A similar shift in old Quaternary terrace gravels that once crossed the fault has also taken place in the same area. Along the north side of the San Gabriel Range on the border of Mohave Desert, similar shifts of a mile or more appear to have taken place. Here, however, the evidence is contradictory. The mouth of Little Rock Creek, for example, appears to have been shifted a mile or more southeastward on the north side of the fault, yet the mouth of Rock Creek, a few miles southeast of Little Rock Creek, would appear to have been shifted in the opposite direction. It is possible that the apparent anomaly of offset at Rock Creek can be explained either by movement of individual blocks in the fault zone or by a broad upwarp to the southeast that begins abruptly at Rock Creek, but the problem is too complex to discuss in detail in the present paper. Farther northwestward, between Little Rock Creek and the Southern Pacific track, terrace remnants—detrital slopes composed of Pelona schist cobbles—lie north of the fault directly opposite granite hills that border the fault on the south for many miles. From the known distribution of the Pelona schist south of the fault, no reasonable conclusion can be drawn other than that the terraces of schist material north of the fault have been shifted several miles southeasterly along the fault, for their only possible source is from Pelona Mountain, a ridge south of the fault that lies 6 or 7 miles northwest of the point where the terrace remnants are preserved.

Certain structural features strongly suggest southeastward horizontal shift of the rock masses north of the fault. For example, the older upper Miocene beds in Cajon Pass west of Cozy Dell are bent into folds whose

axes trend west and meet the fault at a low angle—a structure suggestive of horizontal drag along the fault. Similar folded structures in Tertiary beds at widely separated places in the fault zone meet parallel branches of the San Andreas fault in the same way. The faults of the San Bernardino Range which branch from the San Andreas meet it in the same manner.

In brief, the only reasonable conclusion from the evidence available seems to be this—a horizontal shift of many miles along the fault is possible but no conclusive stratigraphic evidence of it is obtainable and the structural evidence, although suggestive, does not amount to proof. That horizontal shifts of a mile or even of several miles have taken place is reasonably certain from topographic evidence available, yet it is not certain that these movements have been consistently in the same direction throughout geologic time. Reversal of horizontal movement on the fault at different times and places is seemingly conceivable if the physiographic evidence is actually and not apparently contradictory.

One salient fact does appear definitely. All the movements along the San Andreas fault, both horizontal and vertical, appear to be the result of compression. Except the plane of the main fault, which appears to be nearly vertical, the planes of nearly all the associated or branching faults are the planes of reverse faults. At place after place in the rift zone, one encounters slabs of pre-Tertiary granite thrust over younger upturned Tertiary beds. Magnificent examples of this sort of structure are being studied by Buwalda in the Tejon quadrangle. It is common on a smaller scale throughout the 80-mile sector of the rift studied by the author. Considerable evidence has been obtained by the author regarding the structure of the longitudinal valleys and ridges that characterize the fault zone. Many valleys coincide with long ribbons of Tertiary beds bounded by faults that were found to dip under the bordering ridges of crystalline rock. Structurally, therefore, the valleys are wedge-shaped blocks with a broad base and the ridges are wedge-shaped blocks with a narrow base. This wedge structure so characteristic of the fault zone is obviously the result of compression.

The San Gabriel Mountains south of the fault are bounded on the north by steep reverse faults whose planes dip southwestward under the mountain mass. No more important structural geologic work has been done in southern California in recent years than that of M. L. Hill,<sup>1</sup> A. O. Woodford,<sup>2</sup> F. E. Vaughan,<sup>3</sup> and J. P. Buwalda,<sup>4</sup> which shows conclusively that the great mountain masses bordering the San Andreas fault in southern California are not, as was formerly supposed, horsts of the classic basin-range type, but are masses raised by compression along reverse faults.

Hill showed that the southwest side of the San Gabriel range is bounded by reverse faults which dip northward under the mountain mass. The work

<sup>1</sup> M. L. Hill, *Structure of the San Gabriel Mountains, north of Los Angeles, California*, Bull. Dept. Geol. Sciences, Univ. California Publ., vol. 19, No. 6, 1930.

<sup>2</sup> A. O. Woodford, *Geology of Blackhawk Canyon, San Bernardino Mountains, California*, *Idem*, vol. 17, No. 8, 1928.

<sup>3</sup> F. E. Vaughan, *Geology of the San Bernardino Mountains north of San Geronio Pass*; *Idem*, vol. 13, No. 9, 1922.

<sup>4</sup> J. P. Buwalda, Unpublished work now in progress in the Tejon quadrangle and in the Indio and Mecca Hills of the Salton Basin.

of the author of the present paper along the north side of the range shows that the mountains are there bordered by reverse faults which likewise dip under the mountain mass. The range, then, has the aspect of a great inverted prism of granitic rocks raised by compression.

The western part of the San Bernardino Range, as studied by the author, exhibits a similar structure and exhibits it even more graphically. It so happens that patches of a soft Tertiary formation, the upper of the two Miocene formations determined in Cajon Pass, lie at many places upon the gently sloping granitic surfaces that constitute the higher parts of the San Bernardino Mountain mass, the Tertiary beds dipping parallel with the granite slopes upon which they lie. The crystalline bed-rock slopes of the range are therefore old surfaces of erosion from which most of the soft Tertiary beds have been stripped. They are consequently a perfect index of the mountain structure, and are not, as has been supposed, remnants of erosional base-levels developed in late Quaternary time. Their attitude shows conclusively that the mountains are a series of crustal blocks, each of which is raised on the south along a steeply dipping reverse fault and tilted northward. This part of the range, in brief, is a great asymmetrical bulge or arch raised by compression. Inasmuch as the range is composed of masses of crystalline rocks, the deformation has resulted in reverse faults, shearing and arching. If the range had been composed of sedimentary rocks, the deformation would have resulted in folding and thrusting. It is of interest to note that the remnants of Tertiary beds lying on the tilted slopes of the mountain blocks have much the same interpretative value as the "Louderbacks" of lava on the slopes of basin ranges described by Professor W. M. Davis.

In the opinion of the author, the San Bernardino Range, like the San Gabriel Range, may express on a huge scale a structure analogous to that of the inverted prisms of granite in the San Andreas fault zone where the bounding faults dip under the prisms. It is interesting to note that the eroded scarps of the great reverse faults bounding the ranges differ in no way physiographically from eroded scarps produced by normal faults. Recognition of this fact was first announced by M. L. Hill.

From the attitude of the fault planes bordering the San Gabriel and San Bernardino ranges along the San Andreas rift, it would appear that the San Gabriel mass south of the rift is compressed toward the rift from the south and that the San Bernardino mass north of the rift is compressed toward the rift from the north. Seemingly these compressive forces against the rift from opposite sides have resulted in both vertical and horizontal movements upon the rift. The vertical movements are obvious and are easily proved. The horizontal movements can be proved in terms of a mile or two and conceivably may have resulted in a shift of many miles, but this greater shift can not yet be proved by stratigraphic evidence. A full discussion of the problem will be presented in the paper now being written for the Geological Survey.

The most interesting area along the sector of the San Andreas fault studied by the author is Cajon Pass. This is a focal area, into which many great branch faults converge upon the San Andreas like ribs of a fan. Some of these faults are active like the San Andreas in the sense that they cut late Quaternary deposits. It seems likely that the area about Cajon Pass is the



most intensely faulted of any area of similar size in the western United States. More attention will be given to this area in the author's report than to other parts of the 80-mile sector of the rift studied. It has recently been described by him in considerable detail in a paper entitled "An excursion to the San Andreas fault and Cajon Pass" published in the guidebook of the XVI International Geological Congress.

It is the opinion of the author, based upon his field work along the San Andreas fault, that more of the recent earth movements in the region are the result of doming or arching than has been realized. Recognition of these arched structures was first announced by Robin Willis<sup>1</sup> in a paper describing structures along the San Andreas fault in central California. The conclusions announced by Mr. Willis seem equally applicable to the southern sector of the fault. The San Gabriel mountain mass, where the rift crosses it, is in effect a great arch broken into wedge-shaped tilted blocks by reverse faults. A great part of the San Bernardino range is a similar faulted arch of tilted blocks. (See Vaughan, *op. cit.*, p. 405.) The depression occupied by Cajon Pass is in large part the result of downwarp. Many ridges along and in the San Andreas fault zone are blocks arched down toward the fault. Indeed it does not seem improbable to the author that warping and arching have had as much to do with recent topographic relief as faulting. This arching under compression, which, combined with faulting, has produced tilted wedge-shaped blocks, appears to have been the dominant tectonic process affecting the great crystalline rock masses in late Tertiary and early Quaternary time in the region studied by the author. It is interesting to note that if, at most places, the tilted blocks were rotated back to their original position the planes of the reverse faults upon which the blocks were raised would stand nearly vertical.

The recognition by R. T. Hill of a great series of approximately east-west faults, which are cut across by the northwest-southeast faults of the San Andreas system, seems to the author to be well founded in fact. West of Little Rock Creek and onward to Tejon Pass, fault after fault runs into the San Andreas rift from the west and is cut off at the rift. Most of these are reverse faults. A similar east-west fault structure characterizes the San Gabriel Mountain mass. All along the southern base of the San Bernardino Range, similar east-west faults meet the San Andreas. The range, indeed, as already stated, is composed of a series of tilted fault blocks trending east and west. The faults through the San Bernardino range, however, have a tendency to curve toward the San Andreas at a low angle as they approach it, and to join the San Andreas so gradually that they appear to be branches of the San Andreas system. Here, as elsewhere, it is difficult sharply to delimit the San Andreas fault zone.

One of the outstanding features of the San Andreas fault is its fraying out fanwise into great branch faults south of Cajon Pass. The greatest of these, the San Jacinto fault, is the largest branch of the San Andreas. It extends far southward to and beyond the Mexican boundary, diverging far from the San Andreas in the region about San Geronio Pass, but apparently rejoining it again far southward in the vicinity of the mud volcanoes in Mexico. It is at present probably the most active fault in southern Cali-

<sup>1</sup> R. Willis, *Physiography of the California Coast Ranges*, Bull. Geol. Soc. Amer., vol. 36, pp. 641-678, 1925.



fornia. Within historical time it has been much more frequently active in this region than the San Andreas. Along the western part of the San Bernardino plain between Colton and the tip of the rock ridge between Lytle and Cajon Creeks, the fault is buried under the alluvial filling of the plain and has no surface expression except for a short distance north of Colton where it forms a prominent low ridge known as the Bunker Hill dike. Its course is traceable beneath the alluvium, however, by its effect on the ground-water in the alluvium, a very abrupt drop in the water-table taking place west of the buried fault. In the area between Lytle and Cajon Creeks, the fault comes to the surface. Here it occupies a complex zone several miles wide consisting of several parallel and branching faults. Between the faults lie shattered belts of granite, gneiss and Pelona schist. Which of the faults in the zone is the master fault is not known. One, the Glen Helen fault, determines the south side of lower Cajon Canyon. It exhibits scarps in alluvium and other evidence of recent activity. Another, the Sycamore Valley fault, lies between the Glen Helen fault and Lytle Creek. It is marked by a wide crushed zone and at some places by evidence of recent activity. Still another fault lies just south of Lytle Creek. In this area between Cajon and Lytle Creeks the San Jacinto fault zone just described has approached so close to the San Andreas fault that it is not possible definitely to separate the zones of the two faults. The Glen Helen fault, for example, in lower Cajon Canyon might equally well be considered a part of the San Jacinto or of the San Andreas fault zone. Indeed the buried rock floor of the San Bernardino plain may be regarded as a faulted mosaic pinched between and intimately associated with these two great converging faults, both of which are profound, recurrent, and active. Northwest of this area the two great faults continue parallel and not more than 3 miles apart for many miles across the San Gabriel Mountains, until they finally merge at a point on the north side of the mountains. Most of the north side of the main mountain mass is raised upon the San Jacinto fault, not upon the San Andreas, and the San Jacinto fault is there a reverse fault whose plane dips steeply south into the mountain mass.

Another great fault which branches from the San Andreas fault south of Cajon Pass is the Santa Ana fault. This fault leaves the San Andreas at a very low angle near Waterman Canyon and runs far eastward through the San Bernardino Mountains. The Arrowhead Hot Springs in Waterman Canyon emerge upon this fault. Still another great branch fault is the Mission Creek fault. This fault also branches from the San Andreas at a very low angle near Waterman Canyon, runs nearly parallel with the San Andreas for many miles, and finally curves back again and rejoins the San Andreas fault in the Indio Hills in the Salton Basin. The long canyon of Mill Creek is determined by this fault. The Thousand Palms Springs in the Indio Hills emerge upon it. It is most certainly an integral part of the San Andreas fault system if, indeed it is not now the presently active line of faulting in the Coachella Valley.

South of the Indio Hills, after the San Andreas fault is rejoined by the Mission Creek fault, it becomes difficult to trace. The last point southward where recent activity can be attributed to it is in the vicinity of Mortmar on the edge of the Salton Sea. From there southward the direct prolongation of its line appears to run through the Obsidian Buttes near Niland and

down along the line of the Alamo River toward the Mexican boundary. Perhaps the mud volcanoes below the Mexican boundary lie upon it. In connection with the probable location of the fault, an interesting set of facts has been brought to light recently by C. S. Scofield, of the U. S. Department of Agriculture. Mr. Scofield has found that waters emerging upon the San Andreas fault at many places on the edge of the San Bernardino Valley are relatively high in boron. A notable example is the water of the Arrowhead Hot Springs. Springs a short distance away from the fault are low in boron. Tests of well-waters in Imperial Valley east of the line of the Alamo River show a far higher boron content than wells west of the river. Thus it appears probable that the wells of high boron content mark the line of the fault which in Imperial Valley would seem to be a buried feature analogous to the Bunker Hill dike upon the San Jacinto fault. Air photographs suggest that another branch of the fault runs southeastward toward Yuma east of the sand hills below Niland, and that another buried branch marks the western border of the sand hills and is responsible for their localization. In all probability the buried rock floor of Imperial Valley is, like that of the San Bernardino plain, a mosaic of branching faults lying between and intimately associated with the San Andreas and San Jacinto fault systems.

An interesting feature of the sloping granite surfaces on the north side of the San Bernardino range and in the bordering desert is that in places they are continuous with good examples of the so-called desert pediment or *pan-fan*. Inasmuch as these granite surfaces in places still contain remnants of soft Tertiary beds, showing that the surfaces are exhumed unconformities of Tertiary age, one is led to wonder whether some of the desert pediments are not simply exhumed Tertiary surfaces and are not necessarily the result of erosion in late Quaternary time. An excellent example of one of these pediments that is continuous with the granite surface at the base of a series of soft Tertiary or possibly late Quaternary beds may be seen at the narrows of Mohave River, just north of Victorville. The great desert plain sloping northward from the summit of Cajon Pass appears to be a pediment eroded across gently upturned soft Tertiary and early Quaternary beds and veneered by a thin layer of Quaternary alluvium derived from the San Gabriel Mountains to the southwest. The author has found evidence which supports this conclusion. At a place several miles down the detrital slope from the summit of Cajon Pass a southward-dipping monocline in underlying beds is beveled by the unconformity at the base of the Quaternary alluvium, which is there not over 100 feet thick.

The profound difference in the rocks on opposite sides of the San Andreas fault shows that the fault movements have been of great magnitude, but in the 80-mile sector studied by the writer it is not possible exactly to date them by stratigraphic evidence. The youngest Tertiary formation of definitely known age involved in the fault in this sector is upper Miocene. All that can be said, therefore, is that the movements here are later than the deposition of an upper Miocene formation. Evidence elsewhere, however, suggests that they may have taken place in late Pliocene or Pleistocene time. Evidence elsewhere also indicates that the fault is a very old line of weakness upon which movements have recurred through Tertiary time and probably earlier as well as through Quaternary time. It seems un-

likely that the line of the curiously straight and continuous master fault could have originated as anything but a shear zone on a nearly vertical plane. It is seemingly too straight over great distances to have originated as a normal fault or as a low-angled overthrust. As contrasted with the older Quaternary movements the recent movements seem very small—viewed from high in the air the fault trace is but a tiny crack whose appearance suggests, as it were, the recent and superficial reopening of a buried, older and much wider wound, the fault zone. The writer's impression of the fault is one of gradually dying activity in late Quaternary time, as contrasted with violent activity in the early Quaternary to late Tertiary—yet this impression may be but testimony of the relative shortness of late Quaternary time.

#### GEODETIC WORK IN REGIONS OF SEISMIC ACTIVITY<sup>1</sup>

Congress has continued to authorize geodetic work to be done in regions of active earth movement, and this work has been carried on during the past fiscal year in California following plans that have been under way for some years. These plans, approved by the Director of the U. S. Coast and Geodetic Survey and by the Advisory Committee in Seismology of the Carnegie Institution of Washington, consisted in extending lines of levels across fault zones, reobserving along lines of levels previously established where movement is suspected, and the extension across fault zones of arcs of first-order triangulation with supplemental stations of second-order accuracy within or across the arcs of the national first-order triangulation net. Only once has triangulation been repeated in order to detect earth movements under this plan of operation, and that work consisted of the reoccupation of first-order stations from central Nevada westward to the coast, then down the coast to stations Cuyamaca and San Jacinto, thence eastward to a station in Arizona. Precise levels have also been repeated once. In the active earthquake zone along the southern boundary of California, changes of level of from 2 to 7 inches were observed to have occurred within a period of some 4 years.

During the year just past, an arc of triangulation was extended north-eastward from the vicinity of San Luis Obispo across all the major faults of that region. This arc was tied into San Jose, San Luis, Tepusquet and Castle Mount, all stations of first-order arcs in California. There were included in this arc 25 first-order and 55 second-order stations. Since the arc is 65 miles in length, it will be seen that the supplemental stations of the second-order are spaced quite close together, and this close spacing is emphasized in the immediate neighborhood of each fault trace.

In addition to this work directly in the zone of recent earth movements may be mentioned certain other important work of triangulation and leveling done by the Coast and Geodetic Survey during the year. As is generally known, the appropriation for the geodetic surveys of the country was materially increased for the fiscal year ending June 30, 1931, and that increase was maintained during the past year. With these larger funds, rapid progress has been made in extending arcs of triangulation and lines of levels over the country. Of particular interest to the seismologist are (1) the first-order triangulation in California which includes the arc extending

<sup>1</sup> From information furnished by Major William Bowie, Chief of the Division of Geodesy, U. S. Coast and Geodetic Survey.



throughout the San Joaquin Valley, (2) the arc extending northward from the vicinity of Reno, Nevada, to the vicinity of Lakeview, Oregon, (3) the arc with stations closely spaced along the Sacramento River from Sacramento to San Francisco Bay, (4) similar work from the Sacramento River to Stockton along the San Joaquin River, (5) the arc extending throughout the length of San Francisco Bay and (6) an arc of second-order triangulation extending along the coast from a point just to the southward of San Francisco to Monterey Bay.

The following lines of levels were run during the past year in the region now under seismologic observation: (1) Lakeview, Oregon, to Fernley, Nevada (part), (2) releveling, Los Angeles Area, (3) San Jacinto to Aquanga, (4) Longvale to Dos Rios (2d order), (5) Ukiah to Marysville, (6) Eureka to San Francisco and San Jose, (7) Willow Creek to Hornbrook and (8) Salida to Bishop (part).

As has been mentioned before in the reports of the Advisory Committee in Seismology, all of the triangulation and leveling in the federal nets of the country will be useful should an earthquake occur near any arc or line. The federal government is following the plan of spacing the arcs of triangulation and lines of leveling at intervals of about 50 miles, with cross arcs and lines used for adjusting the nets. There is a strong sentiment at present among engineers of the country in favor of first and second-order lines and arcs spaced at 25-mile intervals. This closer spacing would be equally favorable for seismologic studies.

The Coast and Geodetic Survey has now completed the readjustment of the entire triangulation net of the United States, involving more than 25,000 miles of arcs of first-order work. This adjustment was made in two parts. The first included the arc of triangulation along the 98th meridian and all work to the westward, while the second included the triangulation to the eastward of the 98th meridian. At the request of the Director of the Geodetic Survey of Canada the triangulation nets of eastern Canada and of New York and New England have been adjusted together as a single unit. This is of the greatest importance for the study of the recent earthquakes which have occurred in New England and the St. Lawrence basin. It is the first time, as far as is known, where the triangulation systems of two countries have been adjusted together.

The adjustment of the leveling net of the United States and that of Canada as a single unit, involving some 65,000 miles of first-order levels, had been completed in 1929 up to the point of securing the most probable values of the elevations of the junction bench marks. Since that time, the Coast and Geodetic Survey has been fitting in the intermediate sections between the junction points in order to obtain final elevations at all points along the lines. This work is well advanced, but some unadjusted levels still remain to be corrected at the end of the fiscal year.

Close triangulation of first-order accuracy in the regions of more active earth movement will be continued during the coming year in California.

#### WORK OF THE SEISMOLOGICAL LABORATORY<sup>1</sup>

During the year under report, the work of registration of earthquakes which occur within the region adjoining the local network of stations (ap-

<sup>1</sup> Extracted from the Annual Report of H. O. Wood, Research Associate in Seismology.



proximately a radius of 300 miles—500 kilometers—from Pasadena), the interpretation and measurement of the records of these, and work of research based upon the data thus obtained, has gone forward steadily and satisfactorily; likewise the registration, interpretation and measurement of shocks of distant origin, with investigations based upon the resulting data. Monthly bulletins covering routine teleseismic measurements have been issued and distributed regularly in the usual form, together with special comments and additional mensurational data in the case of phenomena of unusual interest or importance. Special studies both of local shocks and distant ones have been undertaken and some of these have been completed, while others are in different stages of advancement. Reference will be made to some of these below. Experimental work has been carried on as usual, resulting in the improvement of devices already in use, the development of new instruments and auxiliary apparatus, the laboratory testing of these mechanisms, and experimental work of more fundamental nature as well.

The results of the routine measurement of local shocks, amplified by more detailed study in many cases, are also assembled in a monthly report which for some time past has been circulated to a small group of persons co-operating in our work in one way or another, nearly all of whom are located in or concerned with the region immediately involved. Recently a form of report on local shocks has been worked out which will be useful to others also who are interested in the occurrence of earthquakes in restricted regions subject to frequent shocks, with the special problems which are thus indicated. This report should possess general scientific interest for seismologists, also. This more adequate form of monthly report will soon be sent to a more extended list.

The report on local earthquakes will give determinations of epicenters and origin-times as well as possible, with estimates of the quality of these determinations and for each shock, so far as practicable, a number, *M*, calculated directly from the instrumentally recorded amplitude which is an approximate value of the *magnitude* of the shock.

From the study of a large number of local earthquakes registered at the stations of our regional network with torsion seismometers sensibly identical in constants, dimensions and properties, it has been found possible to work out a scale of *shock-magnitude*, rather crude in its present development but capable of refinement as data and experience accumulate.

From diligent comparison of the seismograms of many local earthquakes it has been found possible to estimate approximately the amplitude of registration to be expected in a given case at an arbitrary epicentral distance—such as 100 kilometers—on the basis of the measured amplitudes at the epicentral distances of the stations where the shock was registered. Because the instruments are not strictly identical, due to the different underground conditions at the several stations and probably for still other reasons, these estimated amplitudes show some variation, but departures from the best representative value have not been wide. Thus it has been possible to construct a magnitude scale on a logarithmic basis, in which the number representing the magnitude of the given shock is the logarithm of the amplitude, measured in microns, with which the shock should be registered at an epicentral distance of 100 kilometers by one of the standard short-period torsion seismometers regularly in use in our stations.

In terms of this scale of amplitudes the smallest disturbances recorded, which appear to be earthquakes without any doubt, are of magnitude 0.5 to the nearest half unit. The strongest shocks in the California region recorded by our instruments to date probably do not exceed 6; and these are shocks of considerable destructive potentiality. Thus far, the magnitude most frequently registered is 3, which corresponds to shocks, in cases where the epicenter is in a settled district, felt generally over a small area without damage. This scale of amplitudes is sure to be improved and refined as data and experience accumulate. It probably will need to be extended beyond the number 6.

The study of shocks whose origins are near the station has been advanced materially by the installation and use at Pasadena of the sensitive short-period vertical-component seismometer designed by Benioff, in combination with a short-period galvanometer. A similar horizontal-component instrument and galvanometer, discussed further below, promises to be very valuable in extending and supplementing the data furnished by this vertical-component assembly. Some valuable indications have also been supplied by the "wave" seismograph.

#### EARTH MOVEMENTS RECORDED

In the eleven months (June 1931 to April 1932, inclusive) some 750 local earthquakes have been registered, fewer than in previous intervals of similar duration, chiefly because disturbances followed by aftershocks in considerable number have not occurred. Strong shocks, or even moderate ones, have been few in the immediate region covered by our intensive survey. A little beyond the boundaries of this narrowly limited area, two shocks of destructive magnitude have taken place, one on October 1, 1931, with origin near  $30^{\circ}$  N.,  $115^{\circ}$  W., in Lower California, and one on June 6, 1932, centering near  $41^{\circ}$  N.,  $125^{\circ}$  W. The latter caused an appreciable amount of minor damage in and near Eureka, California. Lesser shocks, though still of potentially damaging magnitude, occurred on September 30 and October 9, 1931, with origins near the head of the Gulf of California. Some half dozen still less energetic shocks have occurred, originating in desert or mountain districts, any one of which would have attracted much attention had its epicenter been situated in or near the more populous areas.

For the interval under consideration the geographic distribution of epicenters presents an aspect very similar to that for previous years, with local differences in the degree of activity of the various small subdivisions of the province, but no marked difference for the map as a whole. The greatest seismic activity in the entire local region continues to be manifested in a relatively small area not far south of the Mexican border, reaching a maximum, apparently, in the neighborhood of the Gulf of California where numerous small shocks have taken place, in addition to the larger ones already referred to.

The segment of the San Jacinto fault situated west of the Imperial Valley has exhibited far less activity than in previous years. No shocks were located positively in this district in the latter half of 1931, and very few in the first half of 1932. The San Andreas fault has continued inactive over the greater part of its extent in Southern California; however, a few shocks have been located definitely along or near its course westward from Tejon

Pass, and a few have been placed in the San Gorgonio Pass region. Also, some have originated to the northeast of the Imperial Valley, probably along its course there and four or five shocks occurred in the Cajon Pass district during January 1932.

Scattering shocks have continued to occur off the coast to the south and west, most of them in the neighborhood of San Pedro Channel and Santa Monica Bay. A few small shocks have been located definitely in the eastern part of Ventura County, not far from Moorpark, Simi and Santa Susana.

The records written at Santa Barbara show that minor shocks continue to occur in small number with origins at small distance, nearly seven years after the occurrence of the destructive shock of 1925. Activity off the west coast of Santa Barbara County has decreased steadily since its peak at or immediately following the powerful shock of November 1927. Recently, activity has been more marked off the coast further north adjacent to San Luis Obispo and Monterey counties.

A shock, well located near Isabella by means of instrumental data, was felt in the neighboring Kern River region on April 19, 1932. This is the second shock to be located positively in this district since 1926. The records written at Tinemaha and Haiwee show that minor shocks have continued to originate in the region comprising the eastern Sierra Nevada, the Owens Valley and the desert ranges to the east. With the present distribution of stations and recording instruments, only the stronger of these shocks can be located with accuracy.

The occurrence of shocks in the Mojave Desert region, unexpectedly brought to light in considerable number and vigor by our seismometric recording, decreased markedly in the latter part of 1931; but in the six months just ended this activity has been renewed. A group of ten shocks originating not far from Barstow, the strongest on April 27, deserve to be mentioned.

During the eleven months (June 1931 to April 1932, inclusive) about 300 teleseismic disturbances have been registered.

Some of the most noteworthy of these, for most of which excellent records have been obtained, were registered on the following dates, with the approximate epicentral regions indicated:

(1) Shocks with records of normal aspect—

1931, August 10, Central Asia

August 16, Texas

September 25, Near Sumatra

October 3, Solomon Islands

October 10, Solomon Islands

1932, February 3, Santiago de Cuba

May 21, San Salvador

June 3, Off the west coast of Mexico.

The ground movement at Pasadena produced by the shock of June 3 was the largest yet registered here in the case of a shock of distant origin—indicated by the records to exceed half an inch, possibly to attain 15 mm. in double amplitude in the north-south direction with a value somewhat less than half this in the east-west direction.



## (2) Shocks with records of deep-focus type—

1931, October 18, South Pacific

1932, January 9, South Pacific

April 4, Region of Japan

May 26, South Pacific

The records of the shock of May 26, from a source nearly the same as that of October 18, 1931, show very large amplitudes in the preliminary phases, indicating very great energy, while surface waves are small or absent. Comparison with the tables and curves published by F. J. Serrase indicates an origin-depth of 0.09 of the earth's radius or more. The shock of September 25, 1931, emanated from a source very near to that of February 10, 1931. Records of these two shocks, and of the shock of October 3, 1931, from the region of the Solomon Islands, have been collected from many stations situated in all parts of the earth. The mass of excellent data available in this assembly of seismograms affords opportunity for research in many directions.

## INSTRUMENT DEVELOPMENT

The automatic radio-receivers for registering the code signals used in synchronizing time at all our stations have been revised in accordance with experience to date. The earlier models were sensitive to changes in battery voltage and in consequence required manual adjustments necessitating visits to the auxiliary stations at undesirably frequent intervals, since these adjustments required training beyond that of the station attendants in most cases. The new form is exceedingly stable over long periods of time and functions satisfactorily with changes in battery voltage as large as  $\pm 35$  per cent.

The experimental automatic device for intensifying the brilliancy of the recording lamps during earthquakes has been found to operate very well. Consequently, after revising the design in a few minor ways to reduce costs, six additional assemblies have been constructed for use at the auxiliary stations.

A few further minor modifications have been made in the design of the ten-cycle quarter-phase impulse motor assembly—used to rotate the recording drums at the auxiliary stations. A bakelite gear has been substituted for one of brass in the case of the shaft which rotates most rapidly. Other manufacturing improvements have resulted in a considerable increase in the uniformity of pole clearances in the quarter-phase motors. This has overcome one of the most stubborn difficulties in the operation of the system.

A major improvement has been made in the seismometer optical system. The optical system which has been in general use in all our stations has consisted of a special incandescent lamp as a linear light-source, a prism for directing the light from the lamp to the seismometer mirror, a spherical lens of 1 meter focus placed immediately in front of the recording mirror, and a cylindrical lens of 2.5 cm. focus just in front of the recording drum. Such a combination of sphere and cylinder does not represent the best arrangement, since it does not permit the horizontal and vertical foci of the recording light spot to be formed at the same point along the optic axis. As a consequence, the well-known double cylinder combination has been sub-



stituted with a considerable improvement in the lines recorded on the seismogram.

The successful operation of the Benioff vertical-component seismograph previously reported upon has led to the design and construction of a horizontal-component instrument having similar properties. As in the case of the vertical instrument the horizontal component has a cylindrical inertia reactor of 100 kilograms mass. It is supported with the axis horizontal by means of six rods arranged to form substantially a double diaphragm mounting such as that formed by the six spokes in the vertical instrument. The restoring force is provided partly by gravity and partly by the tension of the rods when the mass is displaced from rest. An oil-damping mechanism similar to that used with the vertical seismometer provides the required damping. Two electro-mechanical transducers—one mounted at each end—are used to operate simultaneously two galvanometers like those used with the vertical instruments. The constants of this horizontal seismograph assembly are the same as those of the vertical assembly, so that it is now possible, for the first time at this laboratory, to make direct comparisons between seismographic records of vertical and horizontal earth movements.

Further developments have been made with the "wave seismograph" previously described. The experimental model was affixed to the concrete walls of the laboratory, instead of to piers, with the result that it exhibited a certain unsteadiness attributed to building movements. Consequently two "piers" have now been built for the instrument. They consist of two 5.5-foot lengths of 12-inch iron pipe set vertically, sunk to a depth of some 4.5 feet into the granite beneath the laboratory, filled with concrete and cemented in place. The rod, or pipe of the seismograph, 20 meters in length, is fastened to one of these "piers" by means of a steel saddle. The electro-mechanical transducer is bolted to the other "pier" and arranged with two pairs of coils for operating two galvanometers simultaneously. In this improved installation the instrument has operated very satisfactorily and appears to conform to the theoretical expectations.

A property of this type of instrument, which is remarkable and which appears to have been demonstrated both theoretically and practically, is that the frequency response characteristic, within the observable range of earth frequencies, is identical with that of a simple pendulum seismometer having a period and damping the same as that of the galvanometer used to record the wave motion. Thus, with a Moll micro-galvanometer which has a period of 0.2 second, the wave seismograph acts as an approximate accelerometer with a period of 0.2 second, and has a magnification considerably in excess of that obtainable with routine pendulum instruments. With a galvanometer having a period of, say, 15 to 20 seconds, the frequency response characteristic of the wave instrument is identical with that of a Milne-Shaw seismograph. By overdamping the galvanometer, the range of long periods to which the instrument responds can be extended greatly. Overdamping of a pendulum seismograph would also increase its frequency response range, but the consequent loss of sensitiveness and increased difficulties due to tilt, if in effect the sensitivity were restored by increase of magnification, render this method impracticable. The wave seismometer is insensitive to earth tilt. The instrument has been operated successfully in connection with a Moll micro-galvanometer ( $T = 0.2$  sec.), a Moll standard

galvanometer ( $T = 1.3$  sec.) and a galvanometer of period 14 seconds with various values of damping. A galvanometer with period of 40 seconds has been ordered for use in long-period observation.

A portable seismometer of short period has been designed and built for use in experimentation with explosives, blasts, etc., in exploration of the uppermost layers of the earth crust. The inertia reactor of this instrument is a mass of 8 kilograms which is supported by a diaphragm of such stiffness as to provide a period of approximately  $\frac{1}{16}$  second. An oil-damping mechanism similar to that used on the larger vertical-component seismometer provides damping. This instrument operates either as a vertical or horizontal component device. In routine use, the electro-magnetic response of the seismometer is amplified by a vacuum-tube amplifier and recorded by means of an oscillographic assembly.

An oscillographic galvanometer has been developed for recording the earth vibration caused by blasts and surface explosions and the high frequency waves of earthquakes. It is thought that the principle is new. The moving element consists of a ribbon suspension to which a small cylinder of soft iron is fastened eccentrically like the cylinder in the torsion seismometer. Permanent linear magnetic fields are maintained at the ends of the cylinder having a direction perpendicular to the direction of the axis of the cylinder by means of four pole pieces of soft iron communicating with a permanent magnet. A stationary coil surrounds the cylinder without coming into mechanical contact with it. Current through the coil magnetizes the iron cylinder, with the result that its field, thus developed, reacts with the permanent fields in such a way as to cause the cylinder to rotate about the axis of its suspension. A mirror is fastened to the suspension for recording the rotation of the system. The period of the experimental instrument which has been constructed is approximately  $\frac{1}{300}$  second. It appears that periods ranging from  $\frac{1}{5}$  to  $\frac{1}{3000}$  second, approximately, can be obtained in this type of instrument. Some of the advantages are: (1) It permits the use of larger mirrors than are commonly used in oscillographic instruments; (2) the coil can be wound to a high resistance—up to 10,000 ohms—and thus be made to match the output impedance of vacuum tubes directly without the interposition of output transformers; (3) the damping is obtained electro-magnetically.

Work on the ultra long-period seismometer has been confined largely to considerations of design and to experimental laboratory tests. These tests made on the model hinges, and suspension material, have shown that no troubles need be expected from these sources. A satisfactory design for the torsion head, however, has not yet been found.

A large-scale rugged seismometer of simple construction has been designed. This instrument is intended to furnish records (of amplitude) in case an earthquake of such severity occurs that all of the ordinary instruments are put out of action. This device is planned to consist of a vertical shaft supported on a special ball-thrust bearing and held laterally by two self-aligning ball bearings. Attached to the vertical shaft is a long heavy horizontal boom supported by a framework of iron pipe. The recording device is to be attached to the boom at the effective center of oscillation, so that in the case of a simple stylus a one-to-one record of the earth motion will be written.

A simple plate 24 cm. long hung by one end as a simple pendulum by means, say, of a Cardan hinge, has the advantages of the torsion seismometer and in addition an invariable proper period. It is thought that it can be damped adequately by air, or viscous damping methods. Testing is required to determine the effectiveness and adequacy of such damping. If damping effectively comparable with that obtained electro-magnetically as in the torsion instrument can be obtained, the simplicity in design and manufacture, the ease of installation and adjustment, and the invariability of the period, together with the practical invariability of the other constants, give the instrument much promise as a device for registering the motion of local earthquakes. Tests are being conducted with an experimental model to determine the practicability of air damping.

#### PUBLICATIONS

During the year under report a number of papers, several of which were referred to in the report of last year, have been completed and published, as follows:

Hugo Benioff, *Operating Frequency of Regenerative Oscillatory Systems*, Proc. Institute of Radio Engineers, vol. 19, No. 7, pp. 1274-1277, July 1931.

Harry O. Wood and Charles F. Richter, *Recent Earthquakes near Whittier, California*, Bull. Seismological Soc. Amer., vol. 21, No. 3, pp. 183-203, Sept. 1931.

B. Gutenberg and C. F. Richter, *On Supposed Discontinuities in the Mantle of the Earth*, Bull. Seismological Soc. Amer., vol. 21, No. 3, pp. 216-222, Sept. 1931.

B. Gutenberg and C. F. Richter, *Pseudoseisms caused by Abnormal Audibility of Gunfire in California*, Gerlands Beiträge zur Geophysik, vol. 31, pp. 155-157, 1931.

Harry O. Wood and Frank Neumann, *Modified Mercalli Intensity Scale of 1931*, Bull. Seismological Soc. Amer., vol. 21, No. 4, pp. 278-283, Dec. 1931.

Charles F. Richter, *Earthquake of January 28, 1931*, Bull. Seismological Soc. Amer., vol. 21, No. 4, p. 284, Dec. 1931.

B. Gutenberg, *Travel Time Curves at Small Distances, and Wave Velocities in Southern California*, Gerlands Beiträge zur Geophysik, vol. 35, pp. 6-45, 1932.

B. Gutenberg, C. F. Richter, and H. O. Wood, *The Earthquake in Santa Monica Bay, California, on August 30, 1930*, Bull. Seismological Soc. Amer., vol. 22, No. 2, pp. 138-154, June 1932.

Hugo Benioff, *A New Vertical Seismograph*, Bull. Seismological Soc. Amer., vol. 22, No. 2, pp. 155-169, June 1932.

In addition to the studies in progress mentioned above—the development of the magnitude (amplitude) scale, and the investigation of the major teleseisms by means of seismograms lent by many stations—a further study of blasts in Southern California, including a second major blast at Victorville, has been completed by Dr. Richter and the present writer and is ready to be submitted for publication.

An intensive study of the superficial structure of the crust, carried on in the field chiefly by Dr. Gutenberg and Dr. Buwalda, with the aid of Mr.



Henry Salvatori and apparatus made available to the Institution by Dr. J. C. Karcher of Geophysical Service, Inc., has been completed and submitted for publication.

#### RECOMMENDATIONS

It is still of vital importance to the success of the research program inaugurated by the Advisory Committee in Seismology and endorsed by various institutions and guests, that the recommendation repeated in several recent years be strongly emphasized, namely, that the number of stations be increased as soon as practicable. Six stations are now in full and competent operation recording continuously all three components of the earth movements which reach them. This number should be increased to twelve to fulfil effectively the purpose to which the Seismological Laboratory is dedicated.

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*Advisory Committee in Seismology*

**Willis, Bailey**, Stanford University, California. *Studies in comparative seismology*. (For previous report see Year Books Nos. 29, 30.)

Comparative seismology is that branch of earthquake research which deals with seismic activity as a manifestation of terrestrial energy. Its method is to investigate the mechanical structures in which earthquakes occur, to seek the forces involved, and to frame hypotheses relating to the causes.

As developed during the last fifteen years, it is a branch of geologic research and is to be distinguished from the study of seismic vibrations, which constitutes seismometry. While the latter is a mathematical, physical procedure that can be carried out only in the laboratory, the former requires observations relating to the physiography and structural geology of seismic regions by a geologist in the field.

Initial steps in this line of approach to earthquake problems were taken by Branner, Lawson, and H. F. Reid after the San Francisco shock of 1906. Willis began to build on their work in 1918 and has since continued the investigations with broadening scope.

The *Fault Map of California* (1922) and a series of articles entitled *Earthquake Risk in California* were the first tangible results. The great earthquake of November 1922 in Chile drew attention to that region. The results of that study are published in the monograph *Earthquake Conditions in Chile* (Carnegie Inst. Wash. pub. No. 382). A grant for a general survey was used in examining the seismic areas of the eastern Mediterranean, New



Zealand, the Philippines and Japan, during 1926 and 1927. In 1929, East Africa was studied. The work has thus assumed a general character, relating to the globe as a whole.

The areal expansion of the research from the State of California to the world in general has been accompanied by broadening of ideas. The initial concept was that of Reid—an earthquake is an elastic effect of rebound, which occurs on a fault. This explanation, though in many cases correct, raises other questions as to the origin of the fault, the accumulation of the elastic stress, the conditions that localize the development, the source of the energy, the persistence of the activity, and its relations to the past geologic history of the region. The perspective deepens. The study of local, spasmodic earthquake shocks has led to consideration of the more profound problems of geology and geophysics. As a result, the research now includes a general hypothesis of terrestrial dynamics, which may be stated categorically and without argument as follows:

Tectonic earthquakes are chiefly effects of pressure exerted against the margins of continents or suboceanic ridges, from the region of an adjacent basin, during a period of orogenic activity.

The pressure is due to expansion of that disk of the earth's crust that underlies the adjacent basin.

The expansion of the disk is a result of rearrangement of crystals, which undergo metamorphism in adjusting themselves to unbalanced stresses and elongate horizontally, in the direction of the least resistance.

The forces released in the process of metamorphism are molecular, *i.e.* probably electrical rather than merely gravitational; being molecular they are all pervasive in the mass involved and under certain conditions may become cumulative.

The agency which effects the metamorphism is heat, when producing changes of temperature below the melting point. If, on the other hand, the temperature rises to the melting point eruptions of magma follow and volcanoes are an incidental, probably indirect result. There is thus a relation as to cause between earthquakes and volcanoes, each being a manifestation of the same cause, but in different degree.

Thus far, the reasoning in regard to the causes of earthquakes and the conditions affecting them is inductive. It is based on related facts, observed in many parts of the world; it invokes known geologic processes and applies established principles of mechanics, physics and chemistry. There is, nevertheless, opportunity for reasonable doubt, since the reactions occur at depths of many miles in the earth, far beyond the limits of direct observation. For that reason it is desirable to multiply the studies in regions not yet visited, in order that variations, contradictions and alternatives may be noted and given appropriate weight.

Whatever degree of accuracy may ultimately be determined for this working hypothesis, there will remain a background of more speculative problems, among which two now occupy the attention of geophysicists and physicists.

The first of these relates to the sources of heat energy in the interior of the earth. If, as is postulated in the preceding reasoning, large masses of

rock in the solid shell of the earth are from time to time heated to the point of metamorphic reaction and even of melting, from what sources and how is the very great amount of heat concentrated? Opinions differ widely. The obvious suggestions include: original heat of a once molten globe, if the globe ever was molten; or heat generated by gravitational compression, if the earth grew up solidly; or migrating heat from either of these original sources, but later concentrated in the outer shells; or heating by friction and mechanical work; or by chemical reactions; or by radioactive disintegration.

The local concentrations of heat energy demanded by the distribution of seismic activity and volcanoes appeared *a priori* to be consistent effects of radioactive heating, and the problem has been studied accordingly from that point of view. It is found that the disintegration of radioactive minerals would, during millions of years, generate the heat required to melt bodies of rock of the dimensions indicated by the phenomena, provided that the appropriate minerals have been and are *irregularly* distributed in the depths of the solid earth. The slow growth of magma basins of this nature would heat up the overlying crystalline rock and induce that metamorphism which is regarded as the cause of expansion, pressure and earthquakes.

The second problem referred to above relates to the nature and intensity of the molecular forces involved in recrystallization during the process of metamorphism in the depths of the earth. This is a problem in molecular physics, a realm of research in which facts are being sought intensively and opinions are in a state of flux. It seems probable, however, that molecular forces engaged in recrystallization act with intensities far in excess of gravity and under appropriate conditions may set up cumulative stresses of indefinite potency. If that be true, they would satisfy the requirements of seismic activity and also of those grander effects, such as mountain building, of which seismic shocks are but incidents.

An even broader question than either of the preceding is involved in the comparative study of seismic provinces. It relates to the origin of the earth's crust, or continental masses and suboceanic disks, and to the manner of establishment of that condition known as isostasy or equilibrium of masses in the solid shell.

Seismic activity is by some attributed to disturbances of equilibrium and to the efforts of gravity to restore the balance. It is hypothetically linked up with the disappearance of supposititious continents, such as Atlantis and Gondwanaland. It is not overlooked in the search for evidence of continental drifting. The validity of these views can be fairly tested only if we have a rational theory of the origin of the crust and its major features, including the condition of isostasy among large masses.

According to the view which has developed logically as an element of the group of working hypotheses of Comparative Seismology, the actual outer shell of the earth consists of erupted masses, uptruded from within as plateau basalts and batholiths, during the Archean and later geologic periods. Any original crust, of whatever nature, has been overflowed, buried, remelted and re-erupted in the long course of eruptive activity, which is thought to have been going on during the last 1500 million years. Indi-

vidual masses, formerly erupted in the molten state but now solid, are indicated by the component parts of ocean basins and the nuclei of continents. They exhibit rounded outlines, are from 100 to 1000 miles, more or less, in diameter, and presumably tens of miles thick vertically. Each such mass was a local development and was molten during a relatively brief epoch only, just as the Columbia lavas or any batholith of the Laurentian shield was local and temporary.

If this view is correct, the isostatic equilibrium of large masses of the earth's crust follows of necessity. A body of granite, uptruded into the outer shell, would tend to rise to the level determined by its lightness in the molten state. Solidifying, it would sink back to a slightly lower level, but if imbedded in basalt would remain isostatically fixed at a higher level than the surface of that heavier rock. This is thought to have been the process which established the relations of the granitic masses of the continents with reference to the basaltic shell beneath the ocean.

Again, if this is a correct interpretation of the facts, the levels thus fixed are permanent and the features also are permanent in their general outlines, subject to such changes as may be brought about by later effects of eruptivity and adjustment. This bears upon the permanence of continents and ocean basins, an idea first put forward by Dana.

The former existence of Atlantis or Gondwanaland, or of other hypothetical continents which are supposed to have foundered, is thus sharply challenged. And yet, there is no doubt that land bridges of some kind have facilitated migrations of floras and faunas from continent to continent, across oceanic stretches. A solution of this problem is thought to have been found by tracing the courses of ridges between individual basins under the seas and re-elevating them hypothetically to the height of isthmian links. The Isthmus of Panama, which has been pushed up between the Caribbean and Pacific deeps, is the type.

No apology is offered for this excursion beyond the province of seismology in the stricter sense into that of geophysical theory. Earthquakes and volcanoes are the obvious activities of those great forces that have shaped the earth. Through them we may learn to understand the dynamics of the globe; but, also, it is only in the light of a reasonable, coordinated theory of terrestrial dynamics that we may arrive at an understanding of earthquakes and volcanoes.

Completion of the monograph on *African Plateaus and Rift Valleys* is the immediate task in Comparative Seismology. The field work was carried out in 1929-30, and the scientific observations were outlined in *Living Africa*, the narrative of the journey. A broader and more fundamental study of the phenomena is now in progress. Through the work of Edouard Suess and J. W. Gregory the great rift valleys have become classic illustrations of the effects of tension in the earth's crust. They are supposed to have been caused by the collapse of the hypothetical Gondwana continent and its foundering on the site of the present Indian ocean. These views are widely accepted among European geologists and by some in America. They are not sustained by the observed facts, but they can not be lightly dismissed. It is necessary to survey the geology of East Africa in detail and to proceed on the firm ground of sound theory, if we would escape from the



morass of speculative guesses. Since the question of Gondwanaland is involved it has been discussed in cooperation with Professor Schuchert, who has long studied it from the paleontological side. The biological and geophysical lines of reasoning have been harmonized and the arguments are to be published in the Bulletin of the Geological Society of America under the titles *Gondwana Land Bridges* by Schuchert and *Isthmian Links* by Willis.

Another phase of this African study involves the problem of the source of heat to produce large bodies of magma, eruptions of great volume having characterized the activity of the region at widely separated geologic epochs. A survey of the possibilities and of current opinion among geophysicists pointed to radioactivity as the most probable cause and led to a study of that subject. The results have appeared in an article on *Radioactivity and Theorizing*. The ground having been cleared for constructive thinking, the first section of the monograph, dealing with the age of the African plateaus, their sculpture and elevation, has been written. The description and analysis of the rift valleys is next in order. It is expected that the monograph can be completed during the next twelve months.

Future work in Comparative Seismology is designed to extend the surveys to regions that have not yet been examined from this point of view, in order to check the theoretical basis against additional facts.

India offers an appropriate opportunity. Along the southern base of the Himalayas there stretches from Kashmir to Assam one of the greatest of the dislocations of the earth's crust known to geologists. By some it is interpreted as the fracture along which Asia is pushing over India, as the continent drifts southward toward the equator. The reverse action, that of India being pushed northward under Tibet, may be regarded as an alternative explanation and would appear reasonable if it should be found that the Peninsula of India is being squeezed out between converging pressures from beneath the Bay of Bengal and the Arabian sea. The wedge-like form is fitted to this effect. The plan of the actual mountain ranges and higher plateaus of the Peninsula is that which such pressures would produce, so far as can be judged by inspection of maps, and the arrangement of heights and troughs in Permian time was similar. All this accords with the working hypothesis entertained in these studies, but actual observation of the facts on the ground is the only satisfactory basis for so far-reaching an inference. For this reason India is the immediate objective of future work.

The East Indies lie adjacent to India, but present a different phase of the problem, one related to that of the Philippines and Japan. In each of these areas the mosaic of the earth's crust is relatively small. The disks of erupted masses are but two or three hundred miles across and the curving chains of islands are their raised margins, according to the working hypothesis of this research. The Philippines and Japan were surveyed during the journey of 1926-27, but not with that understanding of the significance of observed facts that further experience has developed. Warped and dislocated features of the landscape, raised coral reefs, the distribution of volcanoes, the locations of earthquake foci, the nature and distribution of gravity anomalies,—all constitute a group of related facts, whose corre-



lation and interpretation offer the key to the dynamics of these archipelagoes. For this reason an extended tour of the Dutch East Indies is proposed as a step toward a resurvey of the Philippines and Japan. Whether the three regions should then be discussed in separate monographs or in one comprehensive work is a matter for future determination.

In closing this review of the work in Comparative Seismology to date, a reference to the practical side of the studies may not be out of place. Building to resist earthquakes is the only defense for humanity against the disasters occasioned by shocks. This fact has long been recognized, and suggestions for better building have followed upon each recurrence of quake and fire. It may fairly be claimed, however, that greater advances have been made toward building for safety during the last decade than ever before, and a measure of the progress has been due to the interest stimulated by these researches. On the Pacific coast leading engineers, among whom John D. Galloway and Henry D. Dewell have been most influential, have brought about the adoption of a general building code, with appropriate precautions against earthquakes. The subject of the dynamic reaction of buildings to and during shocks has been made the object of precise research on the shaking table at Stanford University. Material advances in the art of building earthquake-resistant dwellings and modern structures of steel and concrete have thus been made. The city of Palo Alto, where for the past ten years an adequate provision for structural stiffness has been in force, may be said to be insured against a repetition of the 1906 disaster. In the larger cities, old buildings, protected by the death-like grip of property rights, remain a menace; but insurance companies and bankers no longer underwrite the construction of unsafe structures.

The Fault Map of California, published by the Seismological Society of America in 1922, has been extensively used by insurance companies in fixing local risks. It served to stimulate the Geological Survey of New Zealand to prepare a similar map of the islands. After the Napier earthquake, New Zealand authorities drew largely upon American sources of information in framing regulations to prevent a recurrence of destruction. In other directions aid has been extended by means of the printed page or by word of mouth to the peoples of South and Central America, to Palestine and to Greece.



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